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by

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INTRODUCTION

The successful utilization of the Honeybee for either honey production or pollination, necessitates that strong colonies be developed for specific productive periods. Colony development may be limited or enhanced by the time available between the period of inactivity and that of production, by the potential strength of the colony at the beginning of the developmental period, by seasonal conditions during this period, or by management. Bees are creatures of instinct since they behave the same under similar environmental conditions. The conditions affecting their behaviour occur both inside and outside the hive. A knowledge of bee behaviour is the only reliable guide for the beekeeper in attempting to correlate through management, the development of colonies with the conditions of the locality.

The purpose of the work herein presented has been to measure and evaluate factors of environment which affect the development of the normal colony. Beekeeping as an art is extremely old; as a science it is comparatively young. Therefore, its literature still contains an admixture of opinions or unrefined "facts" incorporated with established principles of bee behaviour and methods of management.

The influence of regional differences on methods of practice has given rise to different interpretations of the importance of certain factors, depending upon their prominence in a particular locality. There is evidence that different methods of practice are in part responsible for the differences attributed to regions.

The uncertainty of climatic conditions, the time and intensity of pollen production and honey flows which are determined by locality and season, together with the complexity of the colony's organization do not permit a sharp separation of factors for study. The direct control of any one factor would in many instances introduce abnormal conditions having a greater influence on the colony than the factor measured.

This treatise is considered in three sections with an attempt to establish their interrelationships. First, Brood-rearing which is the basis for colony development. Second, Colony Development which during the active season must be correlated with seasonal conditions that affect the time of the honey flows. Third, Wintering which is necessary to provide colonies capable of rearing brood at the beginning of the developmental period and which determines the level of strength from which they must be developed to productive strength.

ACKNOWLEDGMENTS

It is with greatest pleasure that I dedicate this work to my friend and former teacher of Beekeeping, J. H. Merrill, Ph. D., Massachusetts Agricultural College, 1914. It was under him as his student assistant for three years at the Kansas State Experiment Station that I became interested in this problem and I have endeavored to expand the study along lines which he would have undoubtedly continued had his physical health permitted him to remain in active work. Doctor Merrill has given me many helpful suggestions and has been a constant source of encouragement.

I wish to express my sincere gratitude to my associates in the Department of Entomology for the active interest at all times in the progress of this project. I owe much to Professor H. T. Fernald for his valuable suggestions for the execution of these studies during the first three years while he was directing my thesis. I am particularly indebted to Professor A. I. Bourne for his untiring assistance in going over the manuscript with me to insure clearness of fact.

Lastly, I owe most to my dear wife whose constant encouragement and aid played no small part in making possible the completion of this work.

LITERATURE

The literature relating to Colony Development as viewed by the writer in this paper, is inexhaustible. However, references directly relating to the measurement of factors determining the rate of colony development are not numerous and usually provide only a single contact with some one section of the whole problem. The necessary interpretations are therefore made in the text of the paper by citing these references when they have a direct bearing on an immediate phase of the subject.

The following standard references setting forth principles of bee behaviour and management while not directly used in this work, have had an important and valuable influence on the development of present commercial practices. Root (59) has maintained an encyclopedia of beekeeping through many editions beginning in 1877, which has proved of great value in advancing commercial practice. Phillips (56) has given particular strength to commercial practices through emphasis on bee behaviour or an understanding of the colony and its organization, the life of the individual in relation to the colony, and the cycle of the year. Demuth (7,8) has successfully enumerated the four main

points essential to the production of surplus honey and has interpreted the balance of conditions governing colony development, swarming, and honey storage which he adequately characterized as the "Colony Morale."

METHODS

Normal colonies of full strength were used throughout these studies except where otherwise stated. The writer's use of the term "Normal colony of full strength" refers to one capable of maintaining and reproducing itself which would be accepted by practical beekeepers as either a medium, average, or strong colony for a particular season of the year. The standard 2-story, 10-frame Langstroth hive or its equivalent has been accepted as the minimum equipment necessary for full colony development. The results of Nolan (45), Merrill (28), and others, together with the experience resulting from commercial practice, warrants the use of this hive. The colonies were located where they were exposed to full sunlight, sheltered from prevailing winds, and spaced in such a manner as to minimize the factor of drifting to a point acceptable with commercial practice.

The factor of drifting proved to be far more important than previously recognized. A limited group of colonies to serve as a check against this problem were placed in semi-isolated locations to

eliminate drifting. It seemed desirable to continue most of the observations under accepted conditions of practice.

Periodic measurements of the amount of brood, the number of bees, and the number of pounds of honey contained in each colony were made for the purpose of evaluating colony conditions.

Measurements of Brood

Measurements of the number of square inches of sealed brood were made at regular 12-day intervals; the period representing the average length of this stage. All brood developed by the colony can thus be measured before it becomes transformed into adult bees. Observers of brood-rearing previous to Nolan (45) measured the brood in all stages at 21-day intervals. Such a plan introduces a variable error of considerable magnitude. This is due to the difficulty of readily detecting eggs and early stage larvae. Furthermore, Merrill (34) has shown that as many as 50 per cent of the eggs laid may fail to develop, though such a loss is not typical. In a normal colony, a brood which reaches this stage is reasonably sure to emerge. The writer has found no mortality of sealed brood that had passed the early pupal stage when allowed to emerge above a strong colony. Gooderham (18), however, reports that where sealed brood of all stages is removed from the cluster and allowed to emerge for 12 days in incubators or above strong colonies, the

mortality ranged from 10 to 25 per cent and even greater when water to raise the humidity was not present.

The number of cells of brood was obtained by multiplying the square inches measured by 27.4, the factor representing the number of cells per square inch. Each comb containing sealed brood was placed in a frame marked off into square inches by cross strings. Allowances for incomplete squares of brood were made progressively as each area was measured. The observer found by frequent recounts that this method gave an error not exceeding one square inch per side for the average frame. To further check the accuracy of this method, a series of combs providing more than a thousand square inches of brood were measured in the usual manner. The number of sealed cells were then counted directly with the aid of a unit tabulator. By dividing the number of cells by the square inches measured, 27.4 was obtained as the number of cells per square inch. Actual count of cells in definite areas for a number of combs showed variations of a few tenths in each direction from this factor.

To avoid robbing, the brood combs were usually taken inside the building for measurement.

These were usually away from the colony between 10 and 20 minutes. The loss of heat during this short interval was very small and no signs of chilled brood were encountered under these methods.

Determination of Bees and Honey

The colonies of a series to be determined were screened the night previous with a guard covering the full width of the entrance that provided a clustering space approximately 2.5 inches deep and 10 inches high. Strong colonies during periods of high temperatures were provided with the Miller bottom board, allowing a 2.5 inch entrance instead of the usual 7/8 inch.

High grade Fairbanks scales weighing readily to .5 of an ounce were leveled at the rear of the hive on a metal hive cover. Empty hive bodies equivalent to the number occupied by the colony were kept covered with two hive covers. These were weighed and placed on a wheel barrow ready to receive the frames taken from the colony. The colony with the bees enclosed was next weighed. A bottom board and two hive bodies covered with a damp burlap bag were placed on the colony's hive stand to receive the bees. The colony was then set at right angles to its hive stand

for ease in manipulation. The cover, inner cover, hive bodies, entrance guard and bottom board were placed on the scales as removed from the colony in order to determine the weight of the hive parts. As the frames were removed, they were quickly scanned to locate the queen and the bees were then shaken or brushed into the empty hive on the original stand.

The degree of shaking or brushing of the bees was determined by the presence or the absence of nectar. When nectar was not present, most of the bees were dislodged by shaking and the few remaining were brushed off; when nectar was present, all the bees were brushed off. When the queen was located, she was placed in a Miller introducing cage just inside the entrance of the hive into which the bees were shaken, in order to give her maximum protection. In following this plan, not more than two per cent of the queens escaped the observer. Practically no queens were lost or injured due to these manipulations. The hive bodies containing the frames removed from the colony were kept covered with a damp burlap bag to prevent robbing. When all the combs were free of bees they were closed with the proper cover for weighing.

The hive parts now on the scales were then weighed. They were removed and the equipment containing the combs of honey and brood weighed. By subtracting the original weight of this equipment from the latter, the weight of the frames plus the honey and brood was obtained. The weight of the combs added to that of the hive parts and subtracted from the original weight of the colony gave the weight of the bees removed.

Determination of Bees per Pound

The bees from all parts of the colony are thoroughly mixed as they were removed from the frames and clustered on the inner walls of the two empty hive bodies located on the original stand. A sample from this cluster containing approximately 500 to 700 bees was then taken in a box designed for gassing. A screened opening in this box was placed in contact with the mouth of a pint jar containing calcium cyanide, until the bees appeared lifeless. The sample was immediately weighed to the nearest centigram on a chemical balance; then spread on a paper, divided into rows 3 to 5 bees wide, and their exact number determined with the aid of the unit tabulator. The total weight divided by the number of bees in the sample gave the average weight per bee in milligrams.

The number of milligrams contained in a pound divided by the average weight per bee gave the number of bees per pound. The number of pounds of bees removed from the cluster when multiplied by this factor gave the number of bees contained in the colony.

The method used during 1927 for obtaining the number of bees per pound differed from the above. One or two pounds of bees were secured in a box equipped with a funnel top and then weighed to 1/64 of a pound before and after liberating 500 bees through the funnel. The first method described proved much more rapid and checked so closely with the latter that it was used entirely after the first summer. Less accuracy in weighing of the latter, together with loss of weight by bees while in the box would suggest that the gassing method was the most reliable.

The slight exposure to hydrocyanic acid gas necessary to render the bees inactive apparently did not seriously injure them. They usually revived and entered the colony within 30 minutes. Bees anaesthetized with cyanide do not regurgitate honey from the honey stomach as do those treated with chloroform or ether, a condition which would make weighing difficult. Bees which are at first only

partially anaesthetized with weak cyanide are not subject to a cyanide charge of maximum strength for periods of three to five minutes where if given a strong charge at first, they are rendered inactive in 15 to 30 seconds. A series of cage experiments to test the effects on the life of the workers, using cyanide and chloroform and controlled by bees from the same sample which were not gassed, showed that bees treated with cyanide revived and lived as long as the control bees or an average of eight days under average room conditions; in the absence of light but under similar temperatures, they lived more than two weeks. The bees treated with chloroform revived in about the same time but died in 36 to 48 hours. No observations were made on the activities of bees gassed with cyanide after they entered the colony.

Desborough (9) was one of the first investigators who measured brood and bees although his colony was extremely small. He estimated the number of bees on the basis of 2000 workers in a pint so that his colony containing three pints of bees was considered to have a population of 6000. Most investigators of colony population during recent times have assumed that there were 5000 bees in a pound, having accepted the conclusion of Koons (Root,57). Ebert (13) used

10 bees per gram or 4540 bees per pound. The acceptance of 5000 bees per pound in estimating the number in a colony, introduced an approximate error of 20 to 30 per cent although the error will vary from 10 to 40 per cent, depending upon the colony and conditions under which the weights were taken. The methods used by Koons did not give the true average weight for all bees in the colony. His results approach the average weight of field bees.

The average number of bees per pound for an entire colony was found to vary between 2800 to 4800 due to differences in size of bees, the proportion of young bees to field bees, drones to workers, the effect of the honey flow, amount of honey in the hive, season of the year, and the temperament of the bees at the time of weighing. The majority of determinations gave numbers ranging between 3500 to 4000 bees per pound. Determinations following the end of brood-rearing generally gave heavier bees, while those taken when the colonies were low in stores gave light weight bees. Through the use of reasonably good combs and the practice of decapitating most of the drone brood when making the 12-day counts very few drones (these require 14 to 14.5 days in the sealed stage) were permitted to develop in the experimental colonies.

The following tabulation represents the difference in the weight of emerging bees, nurse bees, and field bees for a typical determination.

Table 1. The Effect of Age on the Number of Bees per Pound.

Data: September 8, 1927.

	Emerging Bees		Young Bees		Field Bees	
Colony	Mg. per Bee	Bees per Lb.	Mg. per Bee	Bees per Lb.	Mg. per Bee	Bees per Lb.
37	100.8	4504	114.3	3972	85.8	5300
39	106.8	4233	120.5	3768	79.7	5686
41	116.5	3900	122.4	3710	94.2	4820
42	105.2	4315	123.4	3680	84.9	5350

The field bees referred to above were separated from the young bees by moving the colony six feet to the rear. A new hive was placed on the original stand of each colony to receive the returning field bees. Each hive contained a frame of unsealed brood and honey to keep the returning bees contented.

Weight of Brood

The amount of honey in the hive was estimated by subtracting .9 pounds for each frame plus the estimated weight of the brood from the gross weight of

all combs. The brood weight was estimated by multiplying the daily rate of brood-rearing by a constant .0042. This constant was calculated from the average weights of brood for all stages (egg to emergence) from data given by Nelson, Sturtevant and Lineburg (43), multiplied by the number of days required for complete development. This was then converted from metric to avoirdupois units. No satisfactory method for estimating the weight of pollen was found, but since pollen may be considered even more valuable to the colony than honey, it is not inconsistent to consider honey and pollen together.

The specific changes in the honey flow were obtained by taking the daily changes in weight of a full strength colony kept on scales throughout the active season. Merrill (30) and Hambleton (19) have shown that the response of different colonies to honey flow conditions are similar, differing only in degree. Merrill's results were obtained from the daily changes of a series of colonies, while Hambleton showed, by comparing the hourly changes for two colonies over an extended period, that the similarity of responses was equally characteristic for short periods.

Comparison of Wintering Practices

The methods employed in wintering were those which various groups of beekeepers have maintained to be the most successful. All colonies were provided with ample stores of good quality. Since the honey stored in this locality was never entirely free of honey dew, at least ten pounds of sugar was fed to each colony to prevent dysentery. The potentialities of colonies were measured in the fall and again in the spring, in respect to the number of bees, age of bees, amount of brood and stores for the purpose of evaluating wintering methods. The plans of giving winter protection are photographed and diagrammed, Plates 18 and 19.

Two problems became evident from the first year's records, which have a very important bearing on the interpretation of changes found in colony strengths. First, that drifting may disturb the balance in colony strengths far more than the method of insulation. Second, that the death rate of bees in the fall is so high that it becomes necessary to limit the comparison between colonies, to those taken on practically the same day. Similarly, in the spring the colony increases rapidly because of brood emergence. The difference of one week in taking records of two colonies may offset any difference due to the method of insulation.

Loss or gain in colony populations is expressed in percentages rather than in number of bees as employed by Merrill (25, 26, 28). A loss of 5000 bees from a colony containing 15,000 bees is more serious than from one containing 25,000. On the other hand, a gain of 5000 would be of greater value to the smaller colony. Colonies showing the least percentage loss in bees and potential bees or the greatest percentage gain are used as the standard for comparison. The consumption of stores is relative, being affected by conditions of wintering but most noticeably by the amount of brood reared during the spring period.

Temperature

Temperatures cited throughout this paper are given on the Fahrenheit scale. Temperature measurements were made by means of thermo-couples, first employed for temperature studies in the honeybee colony by Phillips and Demuth (50). The arrangement and style of equipment used were similar to that described in detail by Wilson and Milum (65) except that 118 and 134 thermo-couples were distributed respectively in two full strength 2-story coloniex as shown in plates 11, 12, etc., in contrast to 44 thermo-couples used in each 1-story colony by them.

The Effect of Methods used on Experimental Colonies

The experimental practices employed throughout this work did not destroy the normality of the colonies under observation except where that was the direct object of the manipulation. The periodic 12-day observations permitted the readjustment of the brood nest and storage space to permit maximum development at all times. The evidence that this was attained is indicated by the fact that the colonies reached maximum strength when compared with the best colonies in commercial apiaries in the white and sweet clover regions, and because their production during the honey flows averaged vastly superior to the remaining colonies in the yard maintained for class purposes.

The brood nest was unrestricted at all times. After measuring the brood areas, those frames containing mostly unsealed brood were placed on the lower hive body; sealed brood and empty combs in the second; empty or partially filled super combs in the third; and partially filled or full super combs in fourth or fifth as required. This readjustment of the brood nest was employed to stimulate maximum development, to obtain full use of all the combs, and to prevent the development of the swarming impulse. In this respect the methods used differed from Nolan (43) who provided

ample room but did not readjust the brood nest at any time. The brood nest is the center of all colony activities. The most pronounced tendency for expansion is upward. The emerging of the sealed brood above gives room for upward expansion of the brood nest. Honey is stored most freely just above the brood. A barrier of honey between the brood nest and empty storage space is not conducive to colony expansion and under such conditions, strong colonies are quick to start swarm preparation.

Strains of Queens

It has not been the purpose in these studies to evaluate strains of bees, but rather to study the development of colonies under recognized commercial standards. The queens purchased were obtained from well known breeders. All queens not otherwise designated were of apparently pure Italian stock although some produced hybrid bees because of mis-mating. When dealing with specific colonies in discussing the results presented herein, reference will be made to the strain or race, age and the method of handling the queen heading each colony. Purchased queens will be designated as Strain A, B, C, D, E, F, or G, the letter symbol referring to the breeder from whom the queens

were obtained. Queens reared locally will be identified by the colony number and strain from which they were bred.

CLIMATOLOGICAL CONDITION

A monthly summary of climatological conditions present at Amherst is included for the period of these observations, Table 6. Climate affects the honeybee colony in two ways: First, in the direct response of individual bees and the cluster as a unit to the influence of temperature, moisture, light, and winds; Second, in an indirect response as these factors affect plant development and thus govern their pollen and nectar supply.

SEASONAL CONDITIONS, POLLEN AND NECTAR SUPPLY

Plants came out of the dormant state abnormally early in the spring of 1927, due to high temperatures and lack of rainfall. Pollen was available from March 16 throughout most of the active season. Soft maples produced more nectar than was used in brood-rearing during the middle of April. The temperature was below normal the last of April and during most of May so that fruit bloom occurred from May 5 to 20, or practically normal, though very little nectar was obtained. Small amounts of nectar were gathered from

mixed sources during early June. This was followed by considerable honey dew between June 10 and 19. A heavy flow from white and alsike clover began June 21 and this was supplemented in early July by basswood. Climatic conditions were very favorable for nectar secretion and bee activity until the flow was ended the middle of July by severe thunder showers, followed by general rains. No further surplus nectar was gathered until a light golden rod flow, September 12 to 18. The season was considered moderately good for honey production.

The "winter" period of 1927-1928 may be characterized as mild; cleansing flights were frequent. The rain fall was excessive during November and December; temperatures were well above normal until March and April when they fell below. The snow fall was unusually light and did not remain on the ground for any extended period.

In the spring of 1928, pollen became available during late March and lasted until the middle of April, a condition which permitted the colonies to expand their brood nest. Subsequent low temperatures, wind, rain, and snow prevented further collection of pollen until May 2. Fruit bloom extended from May 13 to 26, three days of which the scale colony showed a gain of from 3 to 6 pounds. The rain fall was excessive during

June, July, and August so that the honey flow for the season was practically nil, except for a very light flow the first two weeks of July. A golden rod flow permitted the storage of 12 to 15 pounds between September 5 and 17. The season was decidedly unfavorable for the bees and considerable sugar had to be fed in preparing the colonies for winter.

The "winter" period of 1928-1929 was more nearly normal than the previous year. During most of the winter, considerable snow remained on the ground. The mean temperature for December was 4.3° F. above normal while January was 1.3° F. below. The minimum temperature for the winter was 11° below zero.

Spring development was normal in 1929, there being enough high temperature to offset the cool rainy days. Excessive precipitation fell during April and May. Fruit bloom extended from May 5 to 20 with a creditable surplus of nectar being collected from apples May 12 to 20. Considerable honey dew was collected between May 22 and June 10, permitting the scale colony to gain 38.5 pounds. High temperatures, an abundance of sunlight, and lack of rain, following the wet spring provided favorable conditions for a heavy honey flow chiefly from alsike clover, which began June 11 and lasted until July 12 permitting the scale colony to gain 141.5 pounds. The drought persisted and golden rod failed to secrete nectar in September.

The "winter" period of 1929-1930 was practically normal except that low precipitation was evident throughout the fall. The low temperaturesof January and February was more extended than during the previous year. However, these were offset by temperatures above normal during other portions of both months so that the respective means were above normal.

The spring of 1930 was characterized by its extremely rapid development resulting from abnormally high temperatures beginning the first of May. Lack of moisture was evident throughout the spring until after the middle of May. Fruit bloom produced nectar from May 2 to 13, during which time the scale colony gained 55 pounds; peaches, plums, cherries, and apples all secreted nectar in abundance. The previous dry fall together with a dry spring left the clovers in poor condition for nectar secretion so that practically no nectar was obtained from them. Honey dew was collected throughout most of June and a small amount of nectar during a few days of that month. Small gains were made between July 18 and August 7. Golden rod and aster were abundant but the nectar collected between September 12 and 21 was chiefly from aster.

BROOD-REARING

Brood-rearing is the basis for colony development. The amount of brood reared by the colony determines both the rate and limits of its development. It is important that the colony attain a maximum working force by the beginning of the main productive period. The tendency for beekeepers to over estimate the colony's capacity for brood-rearing has been prevalent since Berlepach in 1856 (Nolan,44) obtained 3021 eggs from a queen during 24 hours. The report of this record brought forth numerous exaggerated estimates and some of these reached as high as 6000 eggs per day for extended periods. By the repetition of such unfounded assumptions, many beekeepers have been misled by their enthusiasm and have expected their colonies to reach a productive strength in too short a time. On the other hand, a knowledge of the limitations and the factors governing brood-rearing will give the beekeeper opportunity to properly correlate the development of colonies with conditions in his locality.

Colony Requirements for Effective Brood-rearing

The replacement of the common black German bee in North America, beginning about 1860, by the introduction of Italian queens gave such marked

improvement in the production of colonies that many beekeepers still maintain that a young Italian queen will insure a strong colony whenever it is needed. A prolific laying queen is one factor essential to effective brood-rearing. The number of eggs which she will lay and the amount of brood reared are determined by the strength of the cluster, the pollen and honey supply inside the hive, the condition of the honey flow, the number and the position of available cells for expansion, and the colony morale.

Organization of the Brood Nest

Brood-rearing begins in the center of the cluster when the temperature at that point is raised to approximately 93°, provided that both pollen and honey are available to the bees. This may occur even before the first spring pollen and nectar is collected. The brood nest is typically arranged in spherical form, the different stages being distributed in concentric rings in the separate combs of the brood nest with approximately the same brood area being maintained on both sides. When the area is increased in the first comb, smaller areas are filled in combs on either side approximately opposite the center of the larger area. As these areas increase, additional combs are included by a similar expansion along the radii of the spherical brood nest. The tendency to expand the brood nest

upward insures the brood nest being in close contact with the honey supply and one which is favored by the higher temperatures above. The surplus pollen is placed immediately surrounding the entire surface of the spherical brood nest in a rather uniform layer or band. Surplus honey is placed largely above and to the sides, but never below, for permanent storage. Where the combs to either side of the brood nest do not contain sealed honey, the bees tend to move honey to the side of the comb that faces the brood nest, often leaving the opposite side entirely empty and placing honey in the next comb on the side facing the brood nest. No object for this behaviour has suggested itself though it has been repeatedly observed in the colonies under observation. The exact shape of the brood nest will be limited by the shape of the frames. The brood nest is the center of all colony activities and there is a pronounced tendency toward an upward expansion. The brood nest is kept in close proximity to the food supply and when this is increased both pollen and nectar are stored as close to the brood as possible. Empty combs below the brood or above a barrier of several inches of sealed honey are not used effectively for either the expansion of the brood nest or storage of honey. This fundamental organization must be recognized if optimum conditions are to be provided for the expansion of the brood nest or the storage of honey.

Developmental Period of the Worker Brood

The term <u>brood</u> includes all the immature stages preceding the emergence of the adult bee. <u>Unsealed brood</u> includes the egg or embryonic stage and the larval feeding stage. <u>Sealed brood</u> includes a portion of the larval stage, the pupal stage, and a few hours of the adult stage prior to emergence. The egg is deposited in the base of the cell by the queen and normally requires 72 hours for incubation. Lineburg (23) states that just before the egg hatches nurse bees supply a small quantity of royal jelly about the egg and that the moisture from this food is apparently necessary before the larvae can break through the chorion or egg shell. According to Soudek (61) royal jelly is a highly nitrogenous secretion produced by the pharyngeal glands of nurse bees. The newly hatched larvae float for from 2 to 2½ days on a small mass of royal jelly supplied by the nurse bees. At this time the type of food and manner of feeding is altered from mass feeding of royal jelly to progressive feeding during an additional 2½ to 3 days, when the growing larvae receive chiefly pollen and honey. Nelson, Sturtevant, and Lineburg (43) have stated that approximately 10,000 visits from nurse bees are given each individual between the deposition of the egg and the sealing over of the cell, during which time there is an increase in weight from approximately .132 mg. to

approximately 155 mg. After sealing, 1 to 2 days are spent in spinning a thin cocoon, and 2 days of quiescence before the final larval molt produces the pupa; transition from the pupa to the adult takes place from 7 to 7½ days later. The total period from egg to emergence is generally considered to require 21 days. The work of Bertholf (3) on the molts of the honeybee larva indicates that sealing of the brood takes place 8 days after egg laying rather than the usually accepted period of 9 days. Milum (40) states that the temperature within the brood nest determines the length of developmental period which may range from less than 20 to more than 24 days but that 93.46 per cent emerged within an average period of 20.5 days; the majority being sealed between the eighth and ninth day. Stabe (63) found that the maximum weight of the worker larvae was reached in 5 days. Since the length of these stages have an important bearing on the brood observations used as a basis for calculating the bees that should be in the hive at a certain time, the following observations were made on the stages of brood developed by three full strength colonies.

Each queen was confined to a single empty brood comb for 24 hours in a compartment enclosed by queen excluder zinc in the center of the cluster. By exchanging combs every 24 hours, the time of hatching, the beginning and end of sealing, and the beginning and end of brood emergence was noted. Twelve days after a

frame was taken from the egg-laying compartment, it could be reinserted since it was found that even the slowest developing brood would emerge before the new cycle of brood was ready for sealing. By using only 12 frames, the brood nest was maintained quite compact as is typical in the normal brood nest.

It was found from this study that fully 95 per cent of the brood was sealed in 8 days and that it emerged 12 days from the time of sealing, making a total of 20 days from the time of egg-laying. In those cases where the brood combs were placed to the outside of the cluster next to the hive wall, the total period varied between 20 and 23 days (See temperature effects on brood-rearing). However, brood which required 9, 10, or 11 days in the unsealed stage did not have the sealed stage correspondingly increased. A slightly greater number are sealed in less than 8 days and emerge in less than 20 days from egg-laying than exceed these limits. However, this variation does not appear to exceed more than 1 to 4 hours, a period shorter than can be accounted for when comparing the effects of brood-rearing rates on colony development. The use of the 12-day interval, based on the length of sealed brood stage therefore seems entirely logical for the correlated studies treated later under "Colony Development."

Effects of Temperature on Brood-Rearing

Phillips and Demuth (50) showed that brood-rearing normally took place at a cluster temperature about 93°. They pointed out the danger of unseasonal brood-rearing resulting from undue winter activity produced by poor methods of wintering, a condition frequently brought about by low quality stores which result in excessive accumulation of feces. Milum observed that variations in temperature of the cluster hastened or retarded brood development. Dunham (11) by maintaining a colony in a constant temperature case at approximately 93°, found much less brood was developed and that this was badly scattered; upon exchanging the position of this colony with the check, the constant external temperature of 93° suppressed brood-rearing in the latter while the original test colony re-established a normal brood nest. Retarded brood-rearing under such conditions suggests that the normal activity of the nurse bees in brood-rearing is sufficient to appreciably raise the temperature above that of the surrounding air and under the above artificial conditions, the problem of lowering brood temperature by colony activity was apparently more difficult than the production of heat and maintenance of proper temperatures.

Daily temperature records obtained from the full strength 2-story colonies during April, May, and June, and periodic records throughout the remaining portion of the active season just previous to the examination of the brood nest verify the results of previous workers that brood-rearing normally takes place at a temperature of about 93°. Egg-laying expanded to a new area in the hive after the temperature rose to about 93° although this area was occasionally allowed to drop as low as 78° after the eggs were laid. Milum observed that eggs occupying low temperature areas were apparently uninjured but that their period of development was appreciably lengthened. A full strength colony during the active brood-rearing period normally maintained a temperature in the brood nest ranging between 92.5° and 96.5°. The temperature at any point was observed to vary within this range, but usually not more than from a few tenths to one or two degrees.

Brood combs placed next to the hive wall were not maintained at full brood-rearing temperature and the development of the unsealed stages was materially retarded. However, the queen in a normal colony provided with two brood chambers avoids the use of outside combs.

Hourly fluctuation in brood temperatures were observed which occasionally rose above 97° with a maximum of 100°. The first strong flight between 7 to 8 A.M. and a heavy return of bees at about 5 to 6 P.M. were usually accompanied by a temporary rise in temperature.

The brood areas are so definitely defined by brood temperatures within the above mentioned range that in the normal colony (See plates 11 and 12) a brood-rearing cluster may be considered as characteristic as the broodless winter cluster defined by Phillips and Demuth (50). Temperatures from 15 to 20 degrees lower were frequently observed within a few inches of the brood area on the same comb. The heat originating from the metabolism of the brood itself no doubt plays an important part in aiding the nurse bees in keeping the temperature of the brood-rearing cluster uniformly high.

The pronounced tendency for the queen to expand her brood nest upward is apparently the result of a temperature response. Whenever empty combs are made available directly above the active brood nest, a gradual rise in temperature takes place between these combs surfaces, a condition which is not noticed when combs are made available to either side or below. The temperature usually reaches 93° within 3 to 5 days and the queen immediately expands her egg-laying to the

combs above (except in the case of newly drawn combs). This situation is in harmony with the principle that warm air rises. The queen's response to this temperature stimulus provides a definite principle of management applicable to the 2-story brood chamber, namely the periodic reversal of brood chambers. This establishes optimum conditions for the expansion of the brood nest, one of the conditions essential for the elimination of the swarming impulse.

Seasonal Initiation and Suppression of Brood-Rearing

As just shown, the rearing of brood is definitely correlated with a particular temperature range of which 93° is typical. The combination of factors which initiates normal brood-rearing in the spring and suppresses it in the fall have not been clearly analyzed. Any activity of the cluster which will raise the temperature within to approximately 93° for a period of hours is generally accompanied with egg-laying. If both pollen and honey are available in the hive, brood-rearing once started in late winter will usually be continued without interruption. Theoretically, the bees should expend the least possible energy during the winter period in order to prolong their lives, and then resume brood-rearing in the spring when food, particularly pollen, becomes available. The collection of pollen or nectar in the field, accompanied by its storage in the hive would

cause the cluster to be active enough to develop brood temperatures. It is doubtful whether many colonies wait for the activity of food collection to initiate brood-rearing in the spring.

Phillips and Demuth, and others, have found that a colony which is restless from the accumulation of feces and long confinement increase the cluster temperature to the point of brood-rearing.

Merrill (33) suggested a theory that when the cluster is subjected to a sudden drop in temperature following a warm period in which the cluster is temporarily broken, that the bees overdo the generation of heat while reforming the cluster until brood temperatures are reached. The writer, January 1929, observed a sequence of temperature fluctuations followed by brood-rearing in the colony under observation which agreed exactly with this theory although no cluster temperatures were recorded at the time. Temperatures presented in plates 16 and 17, however, do not support this theory. Brood temperatures obtained January 20, plate 17, follow a rise in temperature instead of the previous drop; also brood temperatures have been observed on several occasions to accompany a short flight of bees during the winter period, but these were in no case maintained after the colony quieted down as the outside temperature became unfavorable for bee flight.

Egg-laying was initiated within 24 hours (January 1930) by inserting a heater filament insulated by glass tubing bent in the form of a W which provided about 1.5 inches space between the parallel lines of the tube and extended 6 inches down into the center of the cluster. This was controlled by a thermostat to maintain a temperature of 93° and equipped with suitable resistance to avoid a filament temperature exceeding 100°. Brood-rearing once begun could not be stopped by removing the brood or caging the queen temporarily, a condition which greatly limits the opportunity for the use of this type of equipment.

Brood temperatures usually accompany the taking of sugar syrup from a feeder placed above the cluster, a condition which may be accompanied with egg-laying and possible brood-rearing. However in the fall, brood-rearing so initiated may be stopped with equal suddenness (See plate 14). A colony kept in a constant temperature case at 70° continued brood-rearing for two months after other colonies had ceased and was suppressed only after the case temperature was allowed to fall. The colony had been provided with a large reserve of pollen. Our present evidence indicates that the colony will rear brood whenever the activity of the cluster will provide brood temperatures as long as both pollen and honey are available in the hive. The

majority of colonies begin brood-rearing sometime in February or early March before spring pollen is available. Brood-rearing tends to end in this locality by the first week of October.

Seasonal Brood-Rearing

Brood-rearing is essential to a normal colony when its environment causes the bees to be continually active. It is a function necessary to the colony and since the lives of individual bees are shortened as their activity increases, young bees must be reared to replace those worn out. The broodless period will be discussed in the third section of this treatise under "Wintering," a period requiring the conservation of Bee Energy in order to prolong the life of the individual. It is necessary for the over-wintering bees to resume. brood-rearing when the conditions become favorable in the spring. The amount of brood reared by the colony during the active season will determine the rate of its development, its producing strength at the time of a honey flow, and the opportunity for increasing the number of colonies through either natural swarming or controlled divisions.

Nolan (45) considers that there are three phases to the annual brood-rearing cycle: a period of initial expansion, a major period, and a final contraction period. He states that in the case of the initial expansion period when once entered, it "is

continued in spite of conditions which if occurring later in the season would tend to check brood-rearing." This viewpoint does not seem to harmonize with the usual methodical response which bees make to the influence of their environment. This tendency pointed out by Nolan may be explained through the lack of a sharp definition of factors which have a bearing on brood-rearing. The evidence to be presented under daily variations in egg-laying indicates that where conditions permit, the queen has the capacity for reaching from a period of non-production, a level exceeding 1400 eggs per day within one week (See also plate 11 - brood nest for August 7). The initial expansion period may therefore be limited to a very few days when conditions both inside and outside the colony are favorable. The final contraction period may be equally abrupt when conditions no longer favor brood-rearing as indicated in plates 1 and 2. It should be possible to explain the seasonal variations by measuring the influence of factors determining rates of brood-rearing.

Variation in the Queen's Daily Rate of Egg-Laying

The question frequently arises when considering problems of brood-rearing whether the queen fluctuates in her egg production or whether there is a gradual increase or decrease between two levels as shown by 12 or 21 day measurements. Table 2 shows

the daily fluctuation in egg-laying of three queens. Since counts varied occasionally from 15 minutes to 3 hours from the 24 hour periods, the productions are given as mean hourly rates. The queen in Colony 2 emerged June 4 and probably mated on June 9 or 10. Her first egg production covering a 19 hour period averaged 21.3 per hour and within a week she had attained a rate equivalent to the maximum daily rate of brood-rearing for a good colony. It would seem from a study of the three queens that sharp changes in daily egg production are not likely to occur though short cycles are evident.

Table 2. Daily Variations in Egg-Laying by Queens Heading Normal Colonies.

Colony No. 2			Colony No. 23			Colony No. 60		
Date	Hours	Mean Hourly Rate	Date	Hours	Mean Hourly Rate	Date	Hours	Mean Hourly Rate
June 14	19	21.3	June 14	24.5	67	May 7	24	68
" 15	23.75	25	" 16	24	67	" 8	24	75.8
" 16	23.5	33.4	" 17	25	60	" 9	24	71.7
" 17	25	33.6	" 18#			" 10	24	60.4
" 19	50	50.3	" 19			" 13	48	39.1
" 20	26.5	51.9	" 20			" 14	24	52.3
" 21	23.5	59.2	" 21			June 1	24	36.7
" 22	24	54	" 22			" 2	24	35.6
" 23	24.5	61.1	" 23			" 3	24	39.2
" 24	24	46.7				" 4	24	46.1
" 25	25	49.9	" 25	24	47.1	" 7	70	52.3
" 26	23.5	57.1	" 26	24	56.1	" 13	48	58.4
" 27	27.5	52.1	" 27	27.5	62.8	" 15	48	50.1
" 28	20	61.2				" 16	48	20
July 9	27.5	46.2				" 17##	29	36
" 10	24	48	" 30	24	55.7	" 20	71	40.5
" 21	24	65.8				" 21	24	43.4
" 28	25.5	59				" 22	24.5	48.1
						" 25	72	48.1
						" 27	27.2	41.8
						July 28	26.5	45

June 18 to 23, queen on strips of partially drawn foundation; very few eggs were laid during the 5 day period.

New queen July 17, Colony 60.

Daily Rates of Brood-Rearing

Both Nolan (45) and Merrill (34) have correctly pointed out that the queen lays more eggs than develop to adults. There is, therefore, a fundamental difference between daily rates of egg-laying and daily rates of brood-rearing which should be recognized when comparing results.

Nolan (44, 45, 47), whose brood measurements were more extensive than any other previous worker, obtained a maximum daily average of 1808 from a queen which maintained a rate not less than 1640 for a period of 26 days. On only six other occasions did he obtain averages exceeding 1500, and four of these were successive counts made at 7 day intervals. His calculations were made from measurements of brood in the sealed stage and are thoroughly accurate though slight differences are involved through the change factor representing the cells per square inch from 26.3 to 27, beginning in 1922.

Merrill (33) obtained a maximum of 1720; Brunnich (5) a maximum of 1560; both used calculations based on 21 day brood measurements (all stages) and a factor of 25 cells per square inch. There are slight differences in the size of cells depending upon the foundation used, but their estimates are apparently low, having used a factor 7.3 per cent below that of Nolan's and 8.75 below that of the writer. Their use of 21 days instead of 20 for the total developmental period would have further reduced the average rates 5 per cent. The reductions may have been partially absorbed by the normal mortality of the unsealed brood, particularly eggs.

Brunnich (5) states that Berlepsch 1853 found 38,619 cells of brood in all stages which when divided by 21 gave a daily average of 1855. Three years later he obtained for one queen a record of 3021 eggs deposited in 24 hours. Berlepsch considered this record to be exceptional and decidedly uncommon. Yet it stimulated enthusiastic statements from various beekeepers who applied mathematical calculations to superficial observations on the number of combs containing brood. This situation prompted many to assert that their queen or queens operating in their particular hives were capable of laying three to five or even six thousand eggs daily. The literature on actual measurements made on daily rates of egg-laying reviewed by Nolan (44) reveals no record of colonies with brood rates exceeding 2000 daily.

A maximum average daily rate of brood-rearing of 2005 was obtained for the 12 days prior to June 2, 1928 in Colony 35, during the included observations. Table 3 summarizes the average daily rates of brood-rearing above 1000 cells per day for the four seasons observations.

Table 3. Classification of the Frequency with which Daily Rates of Brood-Rearing above 1000 Occurred during 518 Observations, 1927 to 1930.

Year	1000 to 1099	1100 to 1199	1200 to 1299	1300 to 1399	1400 to 1499	1500 to 1599	1600 to 2005
1927	18	29	18	10	6	3	0
1928	7	14	19	11	8	2	4
1929	9	4	2	1	0	0	0
1930	22	15	19	17	15	2	2
Totals	56	62	58	39	29	7	6

These results substantiate those of the previous investigators who used acceptable methods. Since the investigations have been carried out in widely separated geographic regions it would seem that regardless of the maximum daily rate of egg-laying, brood-rearing seldom exceeds an average daily rate of 1500 to 2000 cells of brood.

The Influence of the Colony

A colony having a large cluster is capable of maintaining temperature suitable for brood-rearing over a greater comb surface than one with a small cluster. It likewise provides more nurse bees for the care of the brood. These two factors enable the colony to increase its rate of brood-rearing as its population increases.

The advantage in providing strong colonies for the honey flow has made it essential that the northern honey producer maintain colonies capable of rearing brood at a high rate. The rate of brood-rearing in each colony has been of greater importance than the total amount of brood reared in the apiary. In the south, where bees are produced for packages, much smaller colonies are the general rule. Furthermore, where packages are utilized for establishing new colonies, two and three pounds of bees have given the most satisfactory results.

This contrast between practices in northern and southern apiaries is the result of experience in the respective regions. The colony's influence on brood-rearing forms the basis for these differences and is responsible for the adoption of the present sized package for the establishment of new colonies.

Merrill (37) by shifting the queens between four colonies from one having the greatest amount of brood to the lowest, showed that the colony determined the relative amount of brood in each, irrespective of which queen produced the eggs. While he did not determine the actual strength of these colonies, they did vary in this respect. He interprets his results as indicating that the queen supported by the largest colony will have the best opportunity for producing the maximum brood nest.

This view is logical and within limits gives a correct interpretation of the colony's influence. It forms the basis for northern apiary practice where it is recognized that only the strong colony is productive. Figures 3 and 4, plate 3, indicate that a colony with 10,000 bees may rear brood at a daily rate of 900 to 1000 and that this rate may increase to a maximum of 1600 (possibly 2000) in a colony containing 40,000 bees.

Viewing this problem from another angle, we find that the colony will develop slower in proportion to its total strength as it increases above 10,000 bees. This relation is expressed as the Percentage Ratio of sealed brood to total bees, Figures 1 and 2, plate 3; 1 to 4, plate 4. The colony containing 10,000 bees may have from 80 to 100 per cent as many cells of sealed brood as it has bees. While in the colony containing 20,000 bees there may be from 60 to 70 per cent and the ratio tends to decrease 10 to 12 per cent for each succeeding increase of 10,000 bees. The available data indicate that where the colony contains less than 10,000, the percentage ratio decreases rather sharply.

Strong colonies reach a greater strength during the developmental period previous to the honey flow than small colonies due to their greater rate of brood-rearing. They are therefore more valuable for honey production. Small colonies develop more brood in proportion to their strength and are therefore of

greater value to the package bee producer. When the two pound package is filled with an over-run sufficient to allow for shrinkage during shipment, it will contain approximately 10,000 bees. This sized package allows the highest possible percentage ratio of brood to bees. Since the initial bees do not survive beyond the emergence of brood from the first two to three weeks of egg-laying, the one to three thousand additional young bees obtained from stronger packages do not give these a profitable advantage. This difference places the stronger package only one to three days ahead of the two pound.

One should bear in mind that the strength of the colony is only one of several major factors affecting the amount of brood reared -- to enumerate: the prolificness of the queen and the percentage of her eggs capable of development; food supply, including both pollen and honey; the amount and position of room for brood-rearing; and working conditions as affected by the honey flow and the colony morale.

The two general tendencies already given are distinct enough to show the practical application of this problem. In addition, a definite mathematical relationship may be foreseen between the colony's strength and the amount of brood it can rear under optimum conditions. Since the majority of colonies

contained between 20,000 and 50,000 bees, the direct interpretations are confined to this particular range.

Assuming that the highest points on the charts represent colonies rearing-brood under optimum conditions, the separate effect of the colony's strength on brood-rearing may be observed. These high points tend to fall on a straight line in Figures 1 and 2, and to scatter in 3 and 4, plate 3. The tendency for the majority of points in Figure 2, to align themselves parallel to this optimum curve as well as do the separate series of points for selected colonies Figure 1, indicates that the colony population has a very definite influence on the amount of brood reared. The slope of this line shows a decrease in the percentage ratio of sealed brood to total bees of 12 per cent for each increase of 10,000 bees between the limits given.

To reconstruct from these data the optimum curve for the daily rates of brood-rearing, a parabola is obtained with its apex at forty thousand. This curve would predict that a colony with 10,000 bees would rear brood at the rate of 700 daily, 20,000 at 1200, 30,000 at 1500, 40,000 at 1600, 50,000 at 1500, 60,000 at 1200, and 70,000 at 700. Since Figures 2 and 4 were constructed from identical data, the two

optimum curves intersect with the same respective points as would be expected. Whether the daily rates on the two extremes decrease in accordance with this curve or at a much slower rate as indicated by these data is uncertain.

The frequency distribution of average daily rates of brood-rearing of colonies varying in strength from 10,000 to 70,000 bees during four seasons (Table 4) shows that the highest daily rates were obtained in colonies having 40,000 bees, the maximum being 2005, while two others reached 1700; 1600 was the highest for 30,000 and 50,000; 1300 to 1400 for 20,000 and 60,000; 1000 to 1100 for 10,000 and 70,000. These maximum rates would give a parabolic curve of the same type as for 1930 alone. Its apex would be higher and would therefore allow for higher daily rates, in all of the respective groups. It would allow the maximum rates obtained in the 10,000 and 60,000 groups of 1930 to fall close to the optimum curve, though still slightly above.

Table 4. Frequency distribution of average daily rates of brood-rearing - 1927 to 1930.

Brood							
2005				1			
1700				2			
1600			5		2		
1500			4	3	2		
1400			11	8	12	4	
1300		8	10	13	9	4	
1200		12	8	10	9	2	
1100	2	10	8	9	5	2	2
1000	9	10		10	19		1
Bees	10,000	20,000	30,000	40,000	50,000	60,000	70,000

In comparing data plotted in Figures 1 and 2, plate 3, and Figures 1 to 4, plate 4, with the optimum curve developed showing the "Percentages Ratios" there is a suggestion that any seasonal condition, tending to depress brood-rearing in one colony, exerts a proportional influence on all colonies according to their strength.

Influence of Honey Flows and Stimulative Feeding

The honey flow is considered by the majority of beekeepers to be the most important external factor for stimulating a colony to a high level of brood-

rearing. Merrill (33, 34) questioned its importance; while Nolan (45) has not sharply defined its influence since he has attempted to correlate the honey flow with the sealed brood when found in the hive instead of with the eggs and larvae which were developed during the period. When discussing this factor, Nolan emphasized the importance of incoming nectar in order to obtain a high rate of brood-rearing but in the description of the different colonies, frequently attributed the restriction of brood-rearing to incoming nectar because of the crowding of honey immediately surrounding the brood nest.

There was no pronounced change in the rate of brood-rearing due to incoming nectar revealed by the data obtained during four seasons. There certainly was no stimulative effect and there were several periods where one might interpret an inhibiting effect due to the crowding of nectar into the brood nest. The average daily rates of brood-rearing for typical colonies are correlated with the conditions of the honey flow occurring during the period in which the sealed brood as measured was developed from the egg through to the sealed stage, in plates 1 and 2. Before attempting to correlate the honey flows with the brood levels of colonies chartered under colony development

(plates 5 to 10, inclusive), it becomes necessary to move the brood levels backward twenty days in the season since the brood-rearing data are there plotted as the brood emerging during the 12 days prior to the cay on which the colony strengths were determined.

In attempting to recognize the influence of a honey flow of a given intensity as expressed by the gain in honey during a twelve day period, consideration should be taken of the number of days during which the colonies actually gained.

In 1927, colonies 19 and 20 reached a level of approximately 1500 without the aid of a honey flow for the period of May 9 to 21; in 1928, colonies 1, 20, and 30 reached levels from 1550 to 1700 for the same period under even less incoming nectar; in 1930, the highest gain came from colony 58 which reached just above 1600 in the absence of a flow from May 22 to June 3.

"Stimulative Feeding" is a practice used in an attempt to duplicate the condition of a honey flow by regular feeding of a thin syrup. Its origin would be difficult to trace, but one point is certain that it must have originated during the period of small hives provided with the minimum of stores in contrast to the modern practice of using large hives provided with an abundance of reserve stores. Beekeepers using

a small hive provided with the minimum of stores for wintering were dependent upon nectar or feeding in order to provide the colony with food for spring brood-rearing. It is logical that in the absence of nectar, those colonies receiving food were stimulated to rear more brood than those without food.

Nelson and Sturtevant (43) found that larvae developed during a honey flow or under "stimulative feeding" gained about 8 per cent in weight before sealing. They did not, however, state the amount of stores present in their experimental colonies.

During 1930, four colonies (Number 43, 46, 48, and 49, plate 2) were subjected to the effects of the so-called "stimulative feeding" to further test the possible effects which the incoming nectar might have on the rate of brood-rearing. The four colonies were very evenly balanced at the beginning of the feeding tests. Queen 43 later proved to be inferior to the other three. Colonies 43 and 46 were fed daily at alternate periods with Colonies 48 and 49 by means of the Boardman entrance feeder during the period in which the brood was developing from the egg to the sealed stage. The brood was not measured until eight days after the last syrup was given. The average daily rates of brood-rearing are based upon the measurements of sealed brood but charted for the period during which

the brood was developing. The tendencies expressed by both colonies within their respective groups were so similar that their daily rates are plotted as the mean for two colonies receiving identical treatment. It can be observed by studying the chart that in every instance where the colonies received syrup, their average rate of brood-rearing shows a smaller increase or a greater decrease from the general trend of the two curves than do the two colonies not receiving syrup. The difference observed is not great enough to seriously affect the colony's development, but their occurrence is so uniformly regular to the presence or absence of syrup that it should be emphasized that "stimulative feeding" does not stimulate a colony to attain a higher rate of brood-rearing when ample reserve stores are present in the hive.

Influence of the Pollen Supply

Parker (49) and Soudek (61) have conclusively demonstrated that pollen is an essential part of the food required by both nurse bees and developing larvae. Parker found that in the absence of pollen, brood could not be developed, and that none of the widely recommended pollen substitutes which the bees will collect, store, and feed to early stage larvae will permit the colony to develop brood. Soudek similarly found that pollen is necessary in order that the pharyngeal gland

of the nurse bees will become active in the production of royal jelly, a secretion required by the queen and all developing larvae during the mass feeding period. Soudek (62) has found under experimental conditions that egg albumen and dried yeast give promise of serving the same function as pollen since both stimulated the activity of the pharyngeal glands.

From the standpoint of practical beekeeping, the pollen supply is the only factor essential to brood-rearing which beekeepers cannot within reason supply at critical periods. The danger of encountering a loss due to a pollen shortage may be reduced by preserving pollen filled combs when stored beyond the immediate needs of the colony. The cells are never completely filled with pollen so that such combs may be taken from the sides or below the brood nest and placed in supers. During a honey flow the bees will fill with honey above the pollen and seal, thus preventing the pollen from drying out or being destroyed by the growth of molds. By providing two or more such combs in each colony when preparing it for winter, the danger of encountering a temporary pollen shortage will be greatly reduced.

No one as yet has determined the amount of pollen that a colony requires for its brood-rearing. It is also very difficult to determine the pollen available except in very relative terms. Its true

importance may only be recognized during a prolonged period when there is no pollen available. Such a period occurred during the spring of 1928 from April 15 to May 1. The 1928 brood curves for four colonies, plate 1, show a daily average of between three and four hundred in colonies capable of rearing brood at a level well above 1200 daily. This dearth of pollen had been preceded by a rather high level of brood-rearing during late March and early April. They had exhausted any reserve carried over from the previous fall and new pollen had not been gathered greatly in excess of their immediate needs. When this was followed by sixteen days of cold inclement weather the colonies exhausted their reserves very quickly. On May 2, most of the colonies had very little sealed brood (and most of this was in late pupal stage). Eggs and larvae from 1 to 2 days old were evident. The fact that early stage larvae were present indicates that the pharyngeal glands of the nurse bees had not ceased entirely to function and this fact enabled the colonies to recover their brood capacity in 4 to 5 days less time than if egg-laying had ceased. Those colonies measured between May 6 and 9 showed a much higher level of sealed brood than those measured from May 2 to 5, due to the influence of incoming pollen beginning May 2. The uniformity of this influence may be further observed by referring to the brood emergence rates

given in plates 6 and 7. The low level of brood-rearing characteristic of July and August 1929 was very probably caused by a shortage of pollen due to a lack of rainfall beginning early in May. However, the difficulty of making satisfactory quantitative measurements of pollen make this point uncertain.

Swarming

The swarming impulse was encountered only once in the course of these studies and this in 1930 when other work interfered with the regular schedule. The consistent practice of placing the main brood nest in the lower brood chamber with the sealed and emerging brood or drawn combs directly above when the records were taken every 12 days, provided favorable conditions for the expansion of the colony. In the spring of 1930, 20 days elapsed after the colonies were examined May 2 before they were again opened. Furthermore, there had been a heavy honey flow during the first two weeks of this period, causing honey to be crowded around the brood nest. Several of the colonies had close to 50,000 bees and queen cells resulting from the swarming impulse containing eggs up to 2 day larvae. These were removed. This was again followed by another 20 day period without the examination when Colony 12 was found to have sealed queen cells and a greatly reduced brood nest. This colony had 15,180 cells of sealed brood on May 22, and only 9,290 on June 10.

Supersedure cells were encountered in most colonies which showed an abnormally small amount of brood in proportion to the strength of the colony. Supersedure is attempted when the old queen is weak or unproductive, a condition usually evidenced by a proportionally small brood nest and from 1 to 3 queen cells in contrast to the production of many queen cells under the swarming impulse when the colony may or may not show the reduced brood nest, depending upon the stage of the swarm preparations.

Races of Bees

The Italian race is generally accepted as possessing more of the desirable qualities than any other. Throughout North America, the bees are predominately Italian. Carnilans and Caucasians are strongly recommended by their advocates as being superior producers due to their supposedly more prolific queens, more vigorous workers which would fly under conditions unfavorable to the Italian, and which should be better able to withstand the severe cold of winter since they have a more northern origin. Six queens each of the Carniolan and Caucasian races were secured from the principal importers and breeders of these respective races. All were successfully introduced.

Three Carniolans were introduced the middle of June 1928 but were all superceded within six weeks after beginning egg-laying. Three new Carniolan queens were obtained from another breeder the first of October the following fall but these proved to be an impure strain and are not considered specifically in comparison with the Italian race.

Three Caucasian queens obtained the middle of June 1928 are referred to under colony development and wintering. Their brood nests were at no time greater than those of Italian queens in equivalent colonies and in most cases were well below the levels of the good Italian queens (See Colonies 14, 40, 20, Tables 8 and 9). Three new Caucasian queens were introduced into Colonies 7, 19, and 35 (Tables 9 and 10) the last of July 1929. Each established normal brood nest in 1929 but queen 7 proved to be a drone layer in the spring of 1930 and was not further considered. The Caucasian queens 19 and 35 were slower in expanding their brood nest than Italian queens 55 and 56 introduced at the same time, and they did not maintain as high a level.

The brood curve for the complete season of 1930 is given, plate 2, for the Caucasian queen 19, while for only the first five periods for 35 after which she was unsuccessfully superseded and an Italian queen later introduced. The Caucasian queens made

similar response to seasonal conditions made by the Italian queen throughout the season. The strengthening of Colony 35 by drifting was undoubtedly responsible for tremendous difference in its brood level between April 12 and 24 and May 2 and 14 (See explanation of plate 10). Nolan (47) has observed that Cyprian queens also respond to seasonal conditions practically identical with the Italians. Differences between the production of queens of different strains of any race are apt to be encountered. There are no data available at this time which demonstrate a superiority in prolificiness of any race over good Italians. Both the Caucasians and Carniolans are supposed to be prolific swarmers yet no sign of swarm preparations were encountered from these races under the methods of management employed in this work.

Hive Protection

The necessity of the colony maintaining rather constant temperatures of about 93° for proper brood-rearing has suggested the possibility of more rapid spring development in heavily insulated than in single walled hives. Furthermore, insulation should serve in preventing high external temperatures from disturbing the colony during the summer when exposed to the sun's rays if they are effective in preventing low temperatures from disturbing the colonies in the

winter. Again, if the commercial double-walled hive proved valuable for wintering, it must not hinder normal development during the active season, and vice versa, if it proved somewhat more valuable under summer management, it should provide adequate winter protection since its initial cost is so much greater that it probably could not justify an additional insulation cost.

To test these questions, four to six of the experimental colonies were housed in a commercial double walled or Buckeye hive during the four seasons observations.

During the summer of 1927, Colonies 19, 20, 29, and 30 were alternately exchanged at each determination of the number of the bees, from Buckeye to single walled hives and back to Buckeye with Colonies 53, 54-47, 31, and 32 on May 29 or 30, June 22 or 23, etc., until the close of the season. The data for these colonies (Table 7, plate 5) show no evidence of either a beneficial or detrimental effect on the rate of brood-rearing or colony development as a whole.

During 1928, colonies 19, 20, 29, 30, 31, 32 (Table 8, plates 6 and 7) were maintained in Buckeye hives during the entire season, while the remaining colonies occupied single walled hives. During 1929 Colonies 1, 19, 29, and 57 (Table 9, plate 8) occupied

Buckeye hives. During 1930, Colonies 19 and 29 (Table 10, plates 9 and 10) occupied Buckeye hives but after May 1 these were without the packed rim to protect the second story and the chaff tray to provide top insulation. Nowhere in these data could any beneficial or detrimental influence from the Buckeye hive be found. General observations indicate that in the absence of a heavy honey flow during mid-summer, colonies housed in Buckeye hives are more apt to cluster out. Those provided with a ¾ inch ventilation tube about 4 inches above the full entrance showed less of the latter tendency than those not so equipped. From the point of practical summer management, the double walled hive is less conveniently manipulated than the single walled hive because single combs have to be handled in contrast to complete hive bodies whenever a readjustment is made in the brood nest.

A survey of the percentage ratios of sealed brood to the total number of bees, obtained for the brood developed during April prior to the removal of the winter insulation, gives no evidence that heavy insulation gives an advantage in brood-rearing over that of light or even no insulation. This point may be observed particularly for the seasons of 1929 and 1930, table 5. It should be noted that all colonies had practically ideal protection from wind. The

season of 1928 must be omitted from this comparison since a pollen shortage practically stopped brood-rearing in all colonies.

Table 5. Influence of Hive Insulation on Early Spring Brood-Rearing.

Protection	1929 No.Bees	Brood Bees	1930 No.Bees	Brood Bees
Quadruple	23,902	47.0 %	25,868	30.6 %
	12,342	84.2	24,129	45.5
	10,558	86.4	20,620	57.1
	5,817	65.5	14,744	50.7
			14,149	58.7
			8,557	39.1
			6,612	33.2
Mod. Dadant	8,092	75.9 %		
	8,071	68.6		
	5,749	88.8		
Leaf Pack	23,601	51.9 %	33,900	46.4 %
	20,456	32.3	27,056	37.1
	10,476	87.3	18,558	61.6
Paper Pack	22,074	46.4 %	28,225	51.1 %
	18,911	52.6	23,245	62.5
Buckeye	25,525	51.5 %	19,224	51.5 %
	24,767	62.2	15,751	74.8
	19,996	58.2	14,352	56.7
	19,099	29.6	9,980	83.2
	12,276	80.8		
Top and Bottom Pack	20,014	60.8 %	36,102	39.6 %
			26,256	48.6
No Insulation			28,814	48.0 %
			19,321	51.5
			19,740	63.9

While it is true that these records do not show the earliest spring brood-rearing, the general condition in which the colonies survived the winter is in harmony with the above interpretation made from these data.

COLONY DEVELOPMENT DURING THE ACTIVE SEASON

Apiary management to be successful must provide colonies with a maximum working force for the beginning of a surplus honey flow. Since colonies vary in strength and honey flows vary in time of occurrence, the degree of the change in colony populations together with those factors affecting the rate of changes have considerable significance to any system of management. Brood-rearing as the basis for colony development was treated in detail in the previous section in so far as the several factors affect the capacity of the colony for brood-rearing.

Variations in Colony Strength

Colony populations may vary from less than 10,000 to more than 70,000 bees, a queen, and either with or without drones or with them present in varying numbers. Colonies containing less than 10,000 bees are seldom practical while those containing more than 70,000 may be considered quite unusual. The effectiveness of the smaller colony is determined by the length

of time available for development prior to the honey flow, or by the purpose for which the colony is operated, i.e. package bees or honey production. Colonies having a population exceeding 40,000 are normally more effective in producing surplus honey or in pollination work. The population of the colony may be determined by a combination of factors including the season of the year, brood-rearing, food supply in the field, the longevity of the workers, death rates, drifting and the system of management.

Seasonal Changes

The normal colony should enter the broodless period for winter in early October with 25,000 to 30,000 bees. No reliable measurements are available for the changes in population during the broodless period, and nothing more than general observations have been made for the early spring brood period until about May 1. The fact that very few dead bees are carried from the hive during the broodless period and that the clusters cover almost as many combs in late February or early March as in October, suggests that the mortality of bees is low for this period. Many bees are sometimes lost during cleansing flights taken during bright sunlight when there is snow on the ground, possibly due to the bees being blinded by the intensity

of the reflected light; once brought to rest on snow they perish because their body temperature (which is approximately 8.5° F. above that of the surrounding air, according to Pirsch, 57) is so quickly lowered to the point where they lose the power of motion. General observations on occasional colonies during the four seasons covered in this study suggest to the writer that a large portion of the over-wintering bees are replaced before the first of May by those emerging from brood reared during late February, March and particularly April. Emerging bees marked during September and early October have been taken during these latter months and one bee marked September 12 was taken on May 13, or 7½ months later, an observation which indicates the possible duration of life in normal colonies.

The active season under practical apiary management extends from May until October or from the unpacking of insulated colonies one or two weeks prior to the opening of fruit bloom until the colonies are ready for packing again in early October. This separation of the active season from the winter season is recognized in this work.

The condition in which the colony survives the winter determines its strength at the beginning of the active season. The colonies included range from

36, 102 (Col. 3, 1930) down to a few hundred bees with the queen where the clusters had apparently been depleted by drifting colony 40, 1928; colony 42, 1929. Successfully wintered colonies should contain 20,000 to 30,000 bees just prior to the fruit bloom, although colonies having 10,000 to 20,000 headed by a prolific queen may develop into productive strength if given two to four weeks longer time before the main honey flow. Package colonies having 10,000 to 15,000 bees and starting without brood require three to four weeks additional time in order to reach an equivalent productive strength when compared with similar over-winter colonies having their brood nest already established. Under favorable conditions for development, the strong colonies referred to will be ready for a honey flow in three to four weeks, the smaller colonies in five to eight weeks, and package colonies in eleven to twelve weeks after installation. In those regions having extended honey flows, especially characteristic of sweet clover, much smaller colonies at the outset may produce satisfactory crops although still not in proportion to full strength colonies. Normal colonies tend to maintain population of from 45,000 to 60,000 workers. The ability of the colony to retain this maximum strength depends primarily upon the amount of brood it has emerging, but also upon the activities of the colony affecting the death rate or the duration of life.

The colony population decreases rapidly during September and early October; this decrease is most noticeable after September 15. Two factors enter into this decline in population. First, brood-rearing which is finally brought to a close in early October; and second, a loss of field bees which emerged prior to September. The fact that Colony 58 (table 18) survived the winter in reasonable strength when consisting of only old bees which were separated from two colonies and united the first of October, indicates that those bees were in reality young.

Length of Life of the Workers

Beekeepers early became interested in the duration of life in bees and by changing the race of the colony's population, they became acquainted with the general principles. The literature contains many references to this subject, all of which point to the general conclusion that bees live six weeks during the honey flow, six to ten weeks in the absence of a heavy flow, and five to seven months during the broodless period. Phillips (55, 56) considers the bee to have at time of emergence a definite amount of energy to expend and that the bee dies when this energy is expended; its length of life being dependent upon the rate of its activity. This view is in harmony with many observed facts and it is accepted by most students

of behaviour. No adequate method has yet been found for measuring this potential energy factor, nor to evaluate the influence which various types of activity have on its dissipation.

The theoretical maximum age of the oldest bees in each colony (Plates 5 to 10, inclusive) have been calculated from the average daily rates of brood-rearing on the assumption that the daily rates of emergence do not vary markedly over 12-day periods and that it is the oldest bees which die since they have had more opportunity to expend their energy. While these assumptions are considered reasonable within limits, the writer does not maintain that all bees originating in one brood nest have exactly the same potential amount of energy nor that accidental death can be ignored as unimportant.

Four general tendencies governing the duration of the worker's life seem apparent from the study of plates 5 to 10, inclusive. First, bees die at an earlier age in small colonies than in large ones, probably due to the proportionally greater amount of brood reared. Second, bees rearing large amounts of brood have shorter lives than when brood-rearing is less intense. Third, bees emerging before the first of September have little opportunity of living beyond the first of October or at least beyond the end of brood-rearing period. Fourth, while the participation

in a heavy honey flow tends to reduce the duration of life, the reduction is no greater, if as great, as that caused by intense brood-rearing. In general, six weeks may be considered a typical maximum age for bees in a full strength normal colony though it may range from four to nine weeks during the active season.

1927 provided the only continuous honey flow with which the included data could be correlated. With the exception of approximately 3000 bees in Colony 19 (Plate 5) all of the bees in the four over-wintered colonies were apparently under 24 days old on May 29; the colonies were small and brood-rearing had been high. During the first period (May 29 to June 22) Colony 19 produced 14 pounds more honey than Colony 20, possibly due to its greater strength. However, the oldest bees in Colony 19 were 18 days older, indicating that the smaller population and more intensive brood-rearing in Colony 20 was a greater factor in shortening the length of life than the greater honey production of Colony 19. The following period (June 22 to July 16) was characterized by a more intense honey flow. The bees in both colonies were about the same age and showed evidence of having been somewhat shortened by the honey flow. The bees in all the colonies lived longer during late July, August and early September in the absence of a honey flow and under increased hive

population. This increase in age was greatest in those colonies having reduced brood-rearing. The high mortality of old bees in late September and early October in all but Colonies 19 and 20 is striking. The last records were taken in these two colonies before the heavy decrease. This is shown by wintering results, Table 15.

The relationship between these influencing factors, cited for 1927, are also evident during the other three seasons. The low rate of brood-rearing which was typical in all colonies during July, August and September 1929, gave in general colonies containing older bees which had not disappeared before the close of brood-rearing. Colonies 55 to 58 gave the most significant data on the duration of life since the factor of drifting bees was minimized in these. The influence of brood-rearing on reduction of the length of life is very evident when colonies 55, 56, and 58 are compared with 57 (Plate 8) which reared the least amount of brood. Furthermore, Colony 57 was wintered in a double walled hive and had a cluster covering 8 to 10 combs early in April, even though this queen laid nothing but drone eggs during the spring. This colony indicates still further that brood-rearing places the highest tax on bee energy of all activities.

The uniform maximum ages obtained during 1930 for Caucasian Colony 19 (Plate 10) accompanying uniform rates of brood-rearing can be taken as significant. This colony received but few drifting bees and very few drifted out until the first two weeks in September. Colonies 56 and 58 (Plate 9) show identical responses to a light honey flow by the shorter lives of their oldest bees on July 7, followed by an increase in length of life under reduced brood emergence following a change in queens.

The theoretical maximum age as calculated does not show the number of bees of that age in any case. This fact may be pointed out in Colony 29, September 15, where the small size of the colony and intensity of brood-rearing would be expected to shorten the duration of life, yet the theoretical maximum age proved to be 60 days. The majority of those bees were under 24 days while the remainder were between 48 and 60 days. Those older bees would not be expected to engage in brood-rearing.

Death Rates

Merrill (29) presented a useful method for comparing the death rate of colonies with their birth rate. However, his data taken for six colonies on June 15 and again on July 15 probably show exaggerated

tendencies due to the use of assumed constants in calculating the number of cells of brood and the number of bees per pound, shown in these studies to vary sufficiently to account for some of the difference developed from his data.

The number of bees which have died during each interval between determinations of the number of bees (24-day periods for the first three seasons; 12-day for 1930) have been calculated for the colonies plotted. This was accomplished (Plates 5 to 10, inclusive) by adding the number of bees which emerged between two periods to the number present in the first and subtracting those present in second. Where brood observations were not made at exactly 12-day intervals, the intervening days were accounted for by using the average of the daily average rates of brood-rearing for the two successive periods in plates 5, 6, 7, and 8; while in 9 and 10, 12-day periods were generally consistent.

The number of bees which die during any period is intimately associated with the strength of the colony, the age of the bees, and the activity in either or both the rearing of brood or the storage of honey. The elimination of old bees at the end of the season appears to be purely a seasonal phenomenon. The strong colony shows a greater number of deaths because it has more bees expending energy. Proportionally, however, the death rate is greater in the small colony

in accordance with the facts shown when discussing the duration of life. When the duration of life is increased by a gain in population, decreased brood-rearing, or the lack of field activity, the number of deaths become less; under the opposite conditions it becomes greater.

The mortality of bees occurring between early September and the close of brood-rearing represents the most striking loss of bees in the normal colony for any period. Unless this is to be considered a purely seasonal phenomenon, the only plausible explanation that has suggested itself is that old bees when caught in the field by the lowering temperature in late afternoon, a change characteristic of the fall period, become chilled and because of their limited reserve energy, perish instead of becoming active the following day when warmed by the morning sun. It has been observed that many bees remain in the field overnight during midsummer and return to their colonies the following morning.

When the colony has reached its maximum strength, it tends to maintain this until sometime after the first of September, unless its level of brood-rearing suddenly shifts, indicating that the colony eventually reaches a point where its death rate about equals its brood emergence.

The fact that Colonies 56 and 58 (Plate 9) gained respectively on an average 744 and 820 bees daily, between May 2 and June 11 during which time they gained 59 lbs.-11 oz. and 71 lbs.-13 oz. of honey, indicates that the death rate need not exceed the birth rate during a moderately good honey flow as concluded by Merrill.

Our present data are insufficient to make any interpretations on the effect of the density of population on either the duration of life or the proportional death rate, particularly where the uncertain factor resulting from drifting has not been excluded. However, Colonies 56 and 58 showed a more marked increase in the length of life under the reduced brood emergence than during the preceding intervals when the smaller number of larvae were being fed or sealed. These two colonies were isolated and were apparently unaffected by drifting. There data may, therefore, be considered to show the most exact relation between the bees which emerge in the colony, the number present, the maximum age, and the number of bees which died during the different periods. Smaragdova (60) found under purely artificial conditions that by increasing the density of population from one to twenty workers in small cages, the duration of life of the individuals was increased. A similar condition has been recognized in the normal colonies herein

considered; yet it is not illogical to assume that there may be an optimum density population above which the life of the bees become reduced.

Drifting

Commercial beekeepers have recognized that certain colonies in any apiary, particularly at the end of a row or at a corner location, gain considerably from the drifting in of bees from other colonies.

Rauschmeyer (58) considers the problem of drifting important under the German Beehouse plan of management where the colonies are located immediately adjacent to each other and often arranged in tiers. His endeavors to overcome drifting led to the use of colors, color contrast, and color patterns. He concluded that drifting could be reduced by painting the entrances with blue or yellow used as separate colors, or where blue and yellow or white and black were used in combination to give a right and left contrast; but that bees could not differentiate between color patterns and therefore these were not efficient markers. In North America it is customary to paint all the beehives white.

The relative location of each colony is shown (Plate ~~9~~ 18). In the main yard, ten feet of space was allowed between each group of two colonies and between rows, with the colonies in the second and fourth rows alternating in position with groups in the first and

third. The entire apiary grounds sloped towards the west so that the quadruple groups were about 3 feet higher than colonies on the west side; Colonies 37 to 54 were on a terrace about 4 feet higher than the lower part of the main yard with an open lawn having a gradual slope rising in front. While there was perhaps slightly more uniformity in the placing of these colonies than in most commercial apiaries, the latter would have nearly twice as many colonies in the same amount of space, a situation that would add to the confusion rather than making it less.

After obtaining evidence of drifting in 1927, four colonies 55 to 58 were located in the lower yard west of the building. Colony 55 was on a level about ten to twelve feet below that of the upper yard, and this sloped sharply downward until Colony 58 was about 4 feet lower than 55. The nature of the shrubbery and contour of the ground gave satisfactory isolation to prevent drifting in these four colonies.

Drifting is not uniform at all times, yet certain general rules seem applicable to the problem as a whole. Many bees returning loaded from the field are inclined to enter the end or corner hives, particularly if these contain strong colonies. The occasional young bee on a play flight is attracted to any colony nearby which shows a stronger flight than

its own. Bees of all ages are apparently confused by uniformity in position of their hive in relation to other hives or groups of hives and therefore drift into colonies having a similar position to their own. As brought out by Rauschmayer, the use of color contrast probably would avoid considerable drifting resulting from too great uniformity in location. Except in occasional cases where the direction of flight places a corner colony in a favorable condition to receive drifters, the gain of the bees which drift into a colony of average strength may be considered to be more or less neutralized by the loss of bees which drift out. This is shown by the fact that the majority of colonies studied did not deviate in general from the tendencies characteristic of those not influenced by drifting.

Two general methods are available for studying the degree of drifting; the use of yellow and black races or by the marking of a large number of bees. Where there are more than two colonies in a yard, the degree of drifting cannot be measured but its importance can be approximated satisfactorily. Both of the suggested methods were utilized and the magnitude of the problem was evident from each. However, the included data refer only to the use of different races.

In practical beekeeping, drifting which radically upsets the balance in colonies, seriously complicates any system of management, making it

necessary to consider each colony separately in contrast to the application of uniform manipulations for all colonies. It may aggravate the spread of bee diseases in the apiary. It may cause beekeepers to select colonies of inferior stock for breeding purposes which had shown high production because of drifting, and not due to the specific characters of the strain. The importance of drifting is so marked that its influence must be prevented probably by colony isolation, before investigational work in evaluating the character of races and strains of bees can be successfully carried out.

In order to determine whether the system used in obtaining the number of bees and amount of brood was responsible for the evident drifting, the records given in Table 12 were taken for 15 colonies which had not been manipulated for over eight weeks. The results proved astonishing and indicate a much higher rate of drifting than could ever be interpreted by comparing the brood emergence with the number of bees, death rates, etc., for the colonies on which these detailed studies have been made. It is the author's opinion that during the entire season there is usually a greater number of drifted bees among the field force than is proportional for the whole colony.

Comparing the location of these colonies, Plate ~~19~~ 18, it will be seen that Italian colonies 12, 20, 24, and 30, having the same relative position in their respective groups as the Caucasian colony 14, had a high percentage of black bees (maximum 35 per cent) while the latter had a high percentage of yellow bees (41.6 per cent). Italian colonies 11 and 13 having the same relative position as the Carniolan colony 19 and Caucasian colony 21, but to the rear, had practically no black bees (1.4 per cent) while the Italian colonies 23 and 29 had an appreciable drift of black bees (17 per cent). The two black colonies, however, showed a high percentage of yellow bees (28.3 per cent). Under each of these groupings, drifting is most noticeable to the side or to the front of any particular colony. The evidence of drifting was relatively small in colonies 40 to 42. It should be noted that these figures do not give a complete estimate of the amount of drifting since they do not show the drifting of Italian bees into Italian colonies nor Caucasian bees into Caucasian colonies.

The drift into Caucasian colony 35, 1930 (See explanation of plate 10) was the most evident example of drifting encountered during any series of colony observation. The percentage of drifted bees ranged between 12.8 and 21.5 per cent, but averaged close to 20 per cent. These percentages were calculated

from samples of 600 to 800 bees taken from the cluster after the bees had become thoroughly mixed during their removal from the combs.

Division and Uniting of Colonies

Colonies 56 and 57 (Table 8, plate 6) were obtained the previous fall by uniting two pairs of colonies; they were redivided May 3 to obtain colonies 55-56 and 57-58. The united colonies survived the winter with a strength comparable with the best colonies of the 1927-1928 series but not with a strength proportional to their fall supply of bees (Table 19). They are therefore considered as unit colonies on May 2 and may be seen to be similar in strength to colonies 24, 1, and 2. Since the percentage ratio of sealed brood to total bees is inversely correlated with the total number of bees increasing above 10,000, the bees from colonies 56 and 57, each supporting two queens produced almost double the amount of brood as the equivalent forces of bees in colonies 24, 1, and 2, each supporting one queen. Since the original bees had practically all died before June 23, there were on an average 1.73 times as many bees available in the combined colonies 55-56 and 57-58 as averaged by colonies 24, 1, and 2. This difference of bees was produced in less than eight weeks at an average cost of one queen and 12 pounds of honey. Judging by the amount of brood

produced, the influence of an additional queen would have been significant in building strong colonies for the honey flow as early as six weeks after the division was made. The combined colonies appear to have bees two weeks older than those with which they have been compared, a condition which might materially reduce the actual value of this greater number of bees during a honey flow. However, only 5.5 per cent of the total bees were older than 40 days and less than 23 per cent over 29 days old.

The removal of brood from colonies 20, 30, and 42 and of bees from colony 37 (See explanation of plates 6 and 7, 1928) and colony 6 (plate 9, 1930) shows a marked retarding influence on the development of these colonies.

The additions of brood to colony 29 and of bees to colonies 30 and 38 (See explanation of plates 6 and 7, 1928) shows a decided stimulating influence on the development of these colonies.

Field Population

Ebert (13) found 35 per cent of the bees by weight returned to their old location after their colony was set back and a new hive placed to catch the returning bees. His colony contained only 12,300 bees when calculated on the basis of 4540 bees per pound for both old and young at best. Gooderham (18)

gives results for a five year period from the separation of the field force between July 9 and August 6. His calculations were based on 5000 bees per pound and obtained a maximum and minimum respectively of 39,687 and 22,187 with an approximate average of 30,000 to 35,000 which represents 6 to 7 pounds of bees.

The results of the separation of field bees from young bees are given for ten colonies, Table 11. The combined forces varied from 25,480 to 70,021 bees from which 14.2 to 67.1 per cent returned to their old locations. It is very evident that the above method did not give a satisfactory separation of the field bees in Colony 37, 1927. The differences in weight between field and young bees, which were not taken into consideration by Ebert and Gooderham, are very noticeable in the results given in the table.

WINTERING

The honeybee colony enters a period of semi-dormancy for winter in those regions where plant life becomes dormant at the approach of low temperatures. Brood-rearing is temporarily suspended; the bees are normally clustered together for the purpose of producing and conserving heat; temperatures are maintained in the cluster suitable for the bees continued existence at minimum activity. During the active season, the life span of worker bees ranges from four to nine weeks. For the winter period, this must be lengthened to from four to seven months and still leave them with energy to rear the first cycle of brood in the spring.

Wintering proved to be one of the most difficult problems of practical beekeeping until comparatively recent years when Phillips and Demuth (50, 51, 52, 53) presented their highly constructive work on this problem. Their work (50) on the winter cluster habits and temperature effects gave the first strong impetus for the solution of the wintering problems. The annual winter loss in the United States still ranges from 6 to 20 per cent of the colonies, according to Phillips (56) and these estimates do not account for the reduced strength of the surviving colonies due to poor wintering. A portion of this loss may be directly attributed to neglect. On the other

hand, the multitude of articles in the bee journals relating to wintering methods, indicate a pronounced tendency among beekeepers to select only one of the several important factors as a key to the solution of the whole problem.

Object and Requirements

The object of wintering is to conserve the energy of bees in order that the colony will have the maximum potential capacity for brood-rearing when plant life renews development in the spring, providing pollen and nectar. At the same time, it is desirable to eliminate useless consumption of stores. The principle back of all methods which accomplish this object is the elimination as far as possible of all factors which in any way disturb the colony, causing it to be unduly active. The disturbing factors may take the form of abnormally high or low temperatures, excess moisture, jarring or manipulation of the hive, excessive accumulation of feces, disturbances from rodents, etc.

Wintering in a practical sense requires that provisions be included which will permit maximum spring development. Since the beekeeper can not or will not recognize the true end of the colony's winter period, this factor must be considered as a part of the requirements for successful wintering.

A normal colony contains from 20,000 to 30,000 bees, all of which have emerged during the four to five weeks preceding the end of brood-rearing. This is necessary for best results. This presupposes the presence of a vigorous queen to head the colony in brood-rearing so that these bees will be produced in the fall and at the same time insure spring development. Her presence is equally necessary during the broodless period in order to stabilize the colony morale. Ample stores (honey or sugar) of good quality, placed above the cluster are necessary to provide food for the bees and prevent excessive accumulation of feces, the primary cause of dysentery. Feces, accumulating from the undigested portion of consumed food during the period bees are confined to the hive, are not discharged until the bees can take flight. Thus, winter stores of poor quality, including some honeys but particularly honey-dew, should not be available to bees during the true winter period. The colony may require 15 to 25 pounds of stores during the broodless period while from 20 to 40 pounds are generally necessary to supplement incoming nectar during spring brood-rearing. The stores of strong colonies in the spring should not be allowed to drop below 10 to 15 pounds because of the danger of reduced brood-rearing. The provision, therefore, of a minimum of 60 pounds of stores for each

colony at the beginning of the broodless period is a good practice. The equivalent of at least two frames of pollen provides valuable insurance that brood-rearing once begun, will continue uninterrupted in the spring. The equivalent of the 2-story Langstroth hive is necessary to provide room for these stores and empty cells for the cluster to form in. The colony should be protected from rapid changes in temperatures by windbreaks and hive insulation.

It may be stated that when the above requirements are met, every colony may be successfully carried through the winter period. The influence of each factor on the degree of success in wintering has not been adequately measured.

The strength of the colony at the end of the winter period determines the level from which it must be developed to maximum strength in time for the honey flow. That hive insulation is desirable in regions where there is a definite winter has been demonstrated repeatedly. The amount of insulation needed for efficient wintering has not been determined except from theoretical deductions from the cluster's response to temperature changes. Since the bees are apparently more active as the outside temperature decreases below the clustering temperature and that activity (Phillips, 55) shortens the life of the bees, the assumption has been that it should be impossible to provide too much

insulation to the hive. There has been a tendency in commercial apiaries during the past ten years to reduce the amount of insulation used for winter. A study of the effects of different amounts of insulation, methods of applying insulation, and the colony strength, on the degree of success in wintering was made a part of this work. All other factors known to be important from practical as well as a technical experience were made as near optimum as possible. Where not optimum, they were consistently uniform for all colonies for the periods of comparison. The results of data obtained during three winter periods, indicate to the writer that the former interpretations of the true function of the hive insulation should be modified.

Winter Cluster Habits

Phillips and Demuth (50) state that the activity of bees is lowest between 69° and 57° in a broodless colony. At temperatures below 57°, the bees tend to group themselves into a definite cluster somewhat spherical in form, by occupying open cells and interspaces between the combs, just below but in contact with their stores.

The bees in the center of the cluster generate heat energy by muscular activity sufficient to maintain a temperature at the surface of the cluster favorable to the surface bees which remain practically

inactive. The surface bees group themselves closely together for the purpose of retaining heat generated within. The temperature inside the cluster tends to bear an inverse relation to that outside when the latter is below the clustering temperature as shown by previous investigators (15, 20, 21, 50, 65). To accomplish this, the cluster becomes more compact as the outside temperature decreases, thus reducing the surface for radiation and at the same time concentrating more bees within to generate heat. While the cluster can not maintain itself on solid combs of honey, it has been observed in the use of the 2-story hive that the cluster prefers to cover several inches of honey per comb as long as there are open cells in the center in order that it can locate at the top of the hive. The cluster tends to avoid combs in which brood has not been reared even more than combs containing considerable honey. The cluster when not large enough to cover the entire upper set of combs prefers to locate in the front end of the frames instead of either the center or the rear. The queen, on the other hand, when confined to the lower hive invariably began her egg-laying to the rear of the comb center, in starting a new brood nest during the active season, and avoided the front third until that room was needed. These differences in behaviour may very possibly be governed by air currents set sent up within the hive. Bruman (4) in considering

the air circulation in the colony observed that precipitation of moisture was heaviest just below the cluster.

Wilson and Milum (65) record similar tendencies in the function of the cluster and its response to external temperatures as given by Phillips and Demuth but point out that not all of the bees join the cluster at 57° nor does the cluster attempt to maintain a surface temperature equivalent to that at which it begins to form. They state that the surface temperature may be allowed to go to approximately 45°, a statement also supported by Hess (20) and Himmer (21).

Armbuster (1) has attempted to show that the winter cluster temperature varies with rhythmical regularity beginning with the production of a maximum temperature slightly above 90°, when activity ceases allowing the cluster temperature to decrease gradually until the surface bees begin to chill, when they again stimulate colony activity.

Hess attempts to show that the center of heat is below the center of the cluster, and presents a theory of ventilation. However, the characteristic placing of honey above and to the end might well have forced the cluster to seek open cells in the lower part of the combs, a situation which would have caused the center of heat to appear low down on the combs but not necessarily below the center of the cluster. The

writer's observations on normal colonies housed in 2-story hives revealed no indication that either of the last two views on cluster temperature were applicable.

Corkins (6) has recently emphasized that the consumption of stores was much greater in colonies subjected to relatively high or fluctuating winter temperatures than when forced to remain compactly clustered during continuous freezing or even sub-zero temperature.

The wintering data obtained the first two seasons did not harmonize with the theory that heavy insulation should give superior results. Temperature studies were made from full strength 2-story colonies in contrast to single story colonies used by other investigators of winter temperatures (excepting Corkins who used 2-story equipment but equipped only the upper story with thermo-couples). The temperatures presented here are mapped in plates 13, 14, and 15, or charted in plates 16 and 17 for the purpose of showing in detail the position of the cluster and the range of temperature both inside and outside the cluster but inside the hive under extremes of hive insulation when the outside temperature ranged between freezing and zero (excepting in a few of the periods given in plate 14). The shifting in position by the cluster in response to the outside temperature makes the graphing method, when used alone, unsatisfactory for showing the exact responses of the cluster.

At temperatures below freezing, the surface of the cluster lies between 43° and 46°. It is impossible to say whether a thermo-couple lies exactly on the surface of 1/8 inch inside or out. The tempetature inside the cluster is maintained high enough that the bees on the surface will have sufficient conducted heat to prevent them from losing the power of motion. If the surface bees lost power of motion, the cluster would literally "freeze" in that position and might soon exhaust its food supply. Such a condition would be similar to an actual separation from their food supply. Honey is sometimes localized in different parts of the hives when the supply becomes low and the colony dies of starvation because it cannot move appreciable distances under low temperatures.

Temperatures shown in series A, plate 13, indicate that extra heavy insulation does not prevent low temperatures from reaching the cluster when the outside temperature approaches zero. There was a difference of 72.6° between the maximum 95.1° and the minimum 22.5°, recorded and most of the space unoccupied by the cluster had a temperature below freezing. One may conclude from this that the cluster itself possesses the remarkable ability of preventing the rapid escape of heat; that the cluster makes no attempt to heat the compartment in which its unoccupied combs are protected, as a room may be heated by a stove; that the entrance

when reduced bears a similar relation to the space unoccupied by the cluster within the hive as an open door to a full sized room. This is further demonstrated by the fact that a double walled hive in a constant temperature case maintained at 64° gave temperatures 8° to 14° below that of the case in the lower hive when the cluster was occupying the upper hive body and the outside temperature approached zero (See January 16, plate 17) and as much as 20° below that of the case when maintained at 74°.

Since hive insulation as applied does not prevent cold air from reaching the cluster, the chief benefit derived from any hive insulation must come about by reducing the rate of temperature change thus permitting the cluster to adjust itself gradually (See plates 15, 16, 17). The tendency for warm air to rise and for the colony to locate in the top of the hive suggests that the most valuable insulation can be provided at the top. However, since the loss of heat from the cluster cannot be entirely eliminated, it should be recognized that the greater the amount of hive insulation, the higher the temperature (though not necessarily above freezing) will be surrounding the cluster but inside the hive. Yet it will be further observed on comparing Plates 16 and 17 that heavy insulation is equally effective in retaining low temperatures within the hive when the outside temperature begins to rise.

It may be stated before discussing the methods of providing winter protection that the mean temperature for Amherst is below 57° during 8 months of the year and below freezing during 3 of these, namely, December, January, February. The necessity for bees to cluster for the production and the conservation of heat is therefore present in the location where the observations were made.

Methods of Providing Winter Protection [1]

The exact locations of the respective colonies identified by number are shown in Plate 18. All colonies were completely sheltered from winds in all directions by an abundance of closely growing trees surrounding the apiary in addition to these diagrammed on the apiary grounds.

Colonies wintered without packing rested on cement hive stands 10" high; the bee escape holes were open in the inner cover; and the entrances were reduced to $\frac{3}{4}$" opening as in all packed colonies. Colonies packed on their summer stands received 10" of top and bottom insulation (plate 19), provided by filling the hollow cement stands and a full depth hive body placed about the inner cover with dry shavings, except in the Leaf Pack where dry leaves were used throughout.

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[1] X" equals measurements in inches.

The Paper Pack was provided by wrapping with a mattress made by overlapping approximately 15 thicknesses of newspaper to give sufficient length and breadth to completely cover the hive, including the top and bottom board; thus all hive joints were covered. The papers were sewn together sufficiently with wrapping cord to facilitate handling. After this was placed on the hive, tar paper was placed around the newspaper mattress with about 2" folded under both the bottom board and telescoping cover. One cleat was used to hold the tar paper where the two ends overlapped along the side of the hive, and another across the entrance bridge where the paper could not be folded under. The Commercial Double Walled or Buckeye hive had walls including the bottom with a total thickness of approximately 3". The 6" chaff tray filled with shavings provided the top packing for this hive.

The Leaf Pack was applied by nailing a board 6" wide across the entrance bridge to hold the packing above the entrance. To this, 2" wire netting, 36" wide was stapled and then looped around the hive sufficient to allow 6" to 8" packing. By packing the corners more rapidly than the hive surfaces, the wire netting was squared up and the side of the packing kept practically vertical. About 7 burlap bags well filled with leaves are required for this pack. The leaves should be packed tight enough that it will be difficult

to force a finger through the packing, in order to prevent its taking in water.

The Single and Double Colony Cases had only 2" of packing on the front, 6" on the bottom, and 9" to 10" on the sides and rear, and 10" on the top. The 3-Colony Case, used for Modified Dadant hives, had 6" of packing below, front, rear, and on top, and approximately 11" at the outer sides of the end colonies. The three entrances of these colonies were separated as widely as possible. The quadruple case provided 11" to 14" above and 6" on all other parts. Leaves were pushed under the floor of the case to prevent a rapid circulation of air beneath the bottom packing. All cases housing more than one colony had a white board tacked between the entrance to give a color contrast on the dark green background of the case as a precaution against drifting.

Cellar wintered colonies were placed in the cellar during early November following a good flight and removed in the spring when the first pollen was available. The second hive bodies containing additional stores for spring brood-rearing were added as the colonies required stores or room. The cellar temperatures ranged from 42° to 52° with the temperature usually between 45° and 48° as shown by thermographic records kept for two seasons.

Definition of Terms used in Interpreting Data

Potential bees represent the number of bees plus the sealed brood present in the hive when the determinations were made. Full stores represents the total weight of honey plus the weight of dry sugar fed. The loss of stores represents the difference between this total and the stores in the hive when the May determinations were made. "P.R." stands for percentage ratio of sealed brood to total bees.

Results of Wintering Methods

The results from wintering a total of 77 colonies during three seasons are given in Tables 14 to 23 and are summarized in Table 24. The colony's number will identify its location as shown in Plate 18. The dates of the fall and spring determination of numbers of bees, amount of sealed brood and honey are given for each colony and must be considered when comparing specific colonies. An early fall record will result in the colony showing a much higher death toll than is normal for the usual winter period, due to the high mortality of the old bees during the last few weeks before the cluster is formed (See Colony Development plates 5, 8, 9, and 10 for death rates after September 1). The importance of this fact was not

realized until the results of the first season (1927-1928) were available. Since the periods of the different colonies varied appreciably during that season, the summary of data for different methods is slightly less significant than the comparison between colonies.

2-Story Double Walled or Buckeye Hive

(See Table 14 for data)

1927-1928. Buckeye Colony 29 gained 22.8 per cent in bees and 42.5 per cent in potential bees between the fall and spring determination, a gain noticeably superior to any other colony in the yard. Except in the case of colonies 19 and 20 on which the fall records were taken two weeks earlier than for the others, and colony 32 which was considerably smaller and housed in only a $1\frac{1}{2}$-story, the Buckeye hives showed more promising results than other methods of packing. If we assume that colonies 19 and 20 were of a similar strength to colonies 29, 30, and 31 on October 8, colony 20 would have shown a larger gain than either colony 30 or 31. Furthermore, if we compare colony 19 with 29, and 20 with 30, the results suggest that possibly more bees drifted from 19 to 29 than between the other pair. There is a suggestion in this series that the stronger colony at the end of

brood-rearing period will show more favorable results in wintering. Colonies 19 to 32 of this group were fed 13.6, 10.2, 17, 23.8, 27.2, and 27.2 pounds of sugar, respectively. It will be noticed that heavy feeding is accompanied by heavy loss of stores. In general, however, the loss of stores is directly correlated to the percentage of gain or inversely to the percentage of loss in the bees or potential bees.

1928-1929. Colonies 1 and 29 in the Buckeye series for this season ranked about equal to the two leading colonies for the season, colonies 20 (leaf pack) and 35 (quadruple). The series does not rank high in the summary due to the poor queen of colony 30 as shown by her P.R. of 28.9 per cent which in comparison with the other colonies of a similar strength should have exceeded 50 per cent and might have been above 60. She was superseded by the colony during the middle of May. The Caucasian colony 14 which was on a par with the colonies 1 and 29 in the fall, lost twice as many bees. The P.R. of 58.2 per cent of this queen was close to the maximum for her colony strength. Colony 13 while not ranking at the top in this series, showed favorable results when the much smaller fall cluster is taken into consideration. Colony 4 had to be eliminated due to the loss of its queen. Colonies 1, 4, 13, 14, 29, and 30 received, respectively, 18, 12, 18, 18, 24, 18 pounds of sugar

in the fall. Comparing equivalent colonies 1 and 29, the latter consumed 5 lbs.-1 oz. more stores but had received 6 lbs. more sugar, further supporting the first season's results which showed that the heaviest loss of stores accompanies the feeding of the greatest amount of sugar. The consumption of stores in other colonies was proportional to their potential strength in the spring, except in the queenless colony where it was excessive.

1929-1930. For this season the Buckeye series was apparently in a most favorable condition in the fall, but the colonies wintered uniformly poorer than did those receiving no protection, top and bottom, paper, or the leaf packs. The queens were satisfactory producers in all but colony 57, which had a drone layer. This colony, however, wintered through quite a large force of bees and its consumption of stores was light. Each colony received 10 pounds of sugar in the fall. Colony 19 was a Caucasian. Colony 1 showed the least loss in bees of the group and was the only one which showed no loss in potential bees. Its consumption of stores was low. Approximately half of its stores had been shifted in the fall to the lower hive thus permitting the cluster to form above. The persistence of clusters in attempting to locate in the upper hives had suggested that perhaps some advantage could be gained if the sealed honey left as a reserve

for spring brood-rearing was placed below the cluster, that it would interfere less with the cluster activity during the winter. The activity in the spring resulting from the tendency to restore the honey to its normal position above the brood might be expected to stimulate a more rapid expansion of the brood nest. It is essential, however, that enough honey be above the cluster for the winter period since it has long been recognized that a colony may starve in winter with honey only a few inches below. The other colonies in this, as well as in all other, groups had the upper combs practically solid with honey, a condition not so evident during either of the previous seasons.

2-Story Single Walled Hives - Newspaper-Tar Paper Pack
(See Table 15 for data)

1928-1929. Following the successful results from the use of the Buckeye hive the first season, the Paper Pack for the purpose of providing a similar amount of protection to single walled hive was introduced for the comparison. For the apiarist operating a limited number of colonies this plan gives a less expensive means of providing similar winter protection.

Colonies 3 and 31, protected by this method, wintered with the very small average loss in bees of 6.3 per cent and a gain of 28.3 per cent in potential

bees. The queens were not of the highest grade as indicated by their respective P.R. of 52.6 and 46.4 per cent which might have been 10 per cent higher in both cases when their colony strengths are considered. Colony 3 received 24 pounds of sugar and colony 31, 18 pounds. The latter lost 5½ pounds more stores than colony 3, probably due to its greater strength. The amount of stores each consumed was approximately equivalent to that of the two best Buckeye colonies, 1 and 29, although these had from 10,000 to 11,000 more potential bees in the spring.

1929-1930. Three colonies, 14, 23, and 55 were wintered with the newspaper-tar paper pack with the least loss of bees and the greatest gain in potential bees for any group of this season. The queens 23 and 55 were performing close to the maximum while the queen 14 was only slightly less efficient. Each colony received 10 pounds of sugar in the fall and the consumption of stores was normal for the strength of the colonies.

2-Story Hives - No Hive Insulation

(See Table 16)

1929-1930. Three colonies, 2, 6, and 56 were wintered without hive insulation and came through in strong condition with less loss in bees than the Buckeye group. Each colony received 10 pounds of sugar

in the fall and the consumption of stores was slightly greater, colony strength considered, than in colonies provided with hive insulation. The somewhat greater loss of bees and of stores by colony 6 may be partially attributed to its fall record being taken one week earlier than for the majority of colonies. The queen of colony 6 was slightly less efficient than either of the other two, though she was not a noticeably poor queen.

2-Story Hives - Top and Bottom Pack
(See Table 17)

1928-1929. Only five out of twenty-three colonies were stronger in the spring than number 11 which was provided with only Top and Bottom packing. The loss of bees and stores was greater than for the Newspaper, Leaf, or Buckeye packs, but the method did not show marked inefficiency when either the colony strength in the spring or the cost of wintering are compared with the other methods.

1929-1930. Colonies 3 and 20 were provided with Top and Bottom packing for this season. The strength of these colonies in the fall was above the average while the loss of stores and per cent of bees was slightly greater than in the case of those insulated. Colony 3 proved to be the strongest in the yard at the spring determination even though it may be considered to have been handicapped by its fall record being taken one week early.

2-Story Hives - Leaf Pack

(See Table 18)

1927-1928. Colonies 24, 49, and 50, which were all packed with leaves, are not easily compared as individuals or with other methods , for two reasons. First, Colony 24 was strengthened in the fall by uniting 10,875 bees from colony 23. Regardless of the method of wintering, colonies made abnormally strong by uniting have shown a heavy percentage loss of bees although they usually wintered strong. Second, 49 and 50 were noticeably smaller than average colonies, and in addition were placed close together and packed as a unit. The difference in loss and gain in the bees of these two colonies would suggest that Colony 49 probably gained through drifting at the expense of colony 50. These three colonies received 13.6, 17, and 20.4 pounds of sugar, respectively in numerical order. The loss of stores was normal for colonies 24 and 49, and extremely small in the case of colony 50 which had only a small cluster.

1928-1929. Colonies 2, 20, and 58 were wintered in the Single Leaf Packs during this season, each receiving 18 pounds of sugar in the fall. Colony 58, however, should not be considered normal since it was made up of old bees from two colonies which had returned to their former stands after their

colonies had been moved to a new location on September 29 for the specific purpose of separating the old bees from the young bees. It was surprising to find that this colony survived the winter, let alone finding them with a potential strength of almost 20,000 by May 5. Its consumption of stores was exceedingly low. Colony 20, while not as strong as the Buckeye Colony 1, showed the greatest gain in bees and potential bees of any colony for the season. The average potential gain for the two normal colonies packed with leaves was slightly under those packed with newspaper. Their average consumption of stores was 3 lbs.-3 oz. less than for this latter group, yet their potential strength was slightly greater.

1929-1930. Colonies 4, 30, and 58 showed a slightly greater loss of bees and a slightly smaller gain in potential bees than those packed with newspaper, the group which ranked highest for the season. The consumption of stores, however, was 4 pounds less. Otherwise the two groups were comparable and both may be considered to have wintered favorably. Each received 10 pounds of sugar in the fall.

2-Story Hives - Single Case-United Colonies
(See Table 19)

1927-1928. Two colonies, 56 and 57, were obtained by uniting two pairs of colonies as indicated in Table 19. They survived the winter in strong condition as has been found characteristic of all colonies made extra strong in the fall by uniting, but showed a heavy loss in bees. The loss as shown by 57 is probably higher than should have been found when compared with the majority of colonies that season, due to the early fall record taken on one of the combined colonies. Colony 56 came through with noticeably fewer bees than did 57 which was possibly due to an inferior queen as evidenced by the lower consumption of stores. Brood-rearing advanced rapidly in most colonies in early spring but was sharply suppressed the last two weeks of April, due to the entire lack of pollen. The P.R. factor, therefore, was of no use in establishing the efficiency of the queen. The colony with a mediocre queen would have replaced fewer of the overwintering bees and consequently consumed less stores. This difference in queens was borne out later in the season (See brood records-Colony 56-57, plate 6). Both colonies received 21 pounds of sugar in the fall.

2-Story Hives - Single Case-United Young Bees

(See Table 19)

1928-1929. Colonies 56 and 57 each contained the young bees from two colonies, separated from the old bees on September 29 by moving them to new locations and later uniting the two pairs. Colony 56 was re-queened during the first week of October with a young Carniolan queen. Both colonies were fed 12 pounds of sugar in the fall and came through in strong condition. However, contrary to what might have been expected, since they had been made exceptionally strong in young bees by the above manipulation and further strengthened by an unusually large amount of late emerging brood, neither colony showed any advantage in strength in the spring above normal colonies. The Carniolan queen in 56 did not perform as favorably as did the Italian queen of 57 and consequently the consumption of stores was considerably lower. The efficiency of the old bees separated from two of the original four colonies and then united to produce Colony 58, was previously described under the Leaf Pack.

2-Story Hives - Two Colony Case

(See Table 20)

1927-1928. Colonies 1 and 2 received a similar amount of protection as given in single colony

cases except that the two colonies were placed side by side and packed as a group. The two colonies survived the winter in good strength but showed a heavy loss of bees similar to the Buckeye colonies in which early fall records (September 24 to 26) were made. The consumption of stores was normal for the strength of the colonies. Each received 17 pounds of sugar in the fall.

1928-1929. Colonies 21 and 22 were wintered in the double case during this season. Both showed comparatively heavy loss in bees. Colony 21 was a Caucasian and while somewhat stronger in the fall, it showed a greater loss in bees and stores than 22. The former received 18 pounds of sugar and the latter 24 pounds.

2-Story Hives - Quadruple Case

(See Table 21)

1927-1928. Four colonies 33, 34, 35, and 36, wintered in quadruple cases had a much higher average loss in bees than did those wintered in Buckeye hives or those packed with leaves. Colony 35 wintered strong, but apparently at the expense of the other colonies, due to drifting. Colonies 33 and 34 each received 20.4 pounds of sugar; 35 and 36 received 17 pounds. The consumption of stores by these colonies averaged less than in the case of the Buckeye or Leaf

Packed groups due to the difference in colony strengths in the spring. Buckeye colonies 19 and 20 which were appreciably stronger than either 33, 34, or 36, consumed practically the same amount of stores as the heavier packed colonies in the quadruple case.

1928-1929. Colonies wintered in the quadruple case for this season bore a similar relationship to those wintered by the other methods, as during the previous season. Colony 35 was again conspicuously strong and showed the second highest gain of all the colonies for the season. Colonies 33 and 36 each received 12 pounds of sugar; 34 and 35 received 18 pounds. Colony 33 was a weak colony in the fall and showed a rather high percentage loss in bees. Colony 34 had hybrid bees resulting from a supersedure Carniolan queen which mated with an Italian drone. This colony was the strongest one of the group in the fall and showed the highest percentage loss of bees. Its northeast location probably contributed to this but the general tendency was also in harmony with other colonies containing Carniolan blood. However, the P.R. of 86.4 per cent for this Carniolan queen does not indicate any lack of capacity for effective egg-laying. The average consumption of stores for this group was higher than in the other groups provided with less insulation

when the colony strengths are considered. Nevertheless, it is generally recognized that the small colony will consume more stores in proportion to its strength than a stronger one. These four colonies substantiate that idea.

1929-1930. For this season two groups of four colonies were used for comparison with the other methods and to gather further data pertaining to the drifting problem in the quadruple case. Colonies 7, 8, 9, and 10 were located at the north end of a row of four quadruple cases, while colonies 33, 34, 35, and 36 were at the south end as in the two previous seasons. Colonies 7 and 35 were Caucasians for the purpose of studying the drifting problem. However, they failed to aid in the solution of this problem because queen 7 became a drone layer in the spring after producing a fine brood nest during the previous August and September, while the Caucasian colony 35 wintered so poorly that there was no opportunity for it to attract drifting bees. The queen of the latter was a good producer and drifting toward this colony during the summer was very pronounced, as previously referred to.

Colony 9 occupied the same relative position as 35 but in the other case. It showed a slight gain in potential bees while all the other colonies wintered in quadruple cases showed a loss. Each colony had the

upper set of combs practically filled with honey and received 10 pounds of sugar. Their total amount of stores ranged from 58 lbs.-3 oz. to 61 lbs.-11 oz. The consumption of stores was again excessive in proportion to the strength of the colonies in the spring.

The drifting factor in the quadruple winter case is summarized in Table 13. It will be seen that the colony having the southwest location in the case generally showed the least loss or the greatest gain except where this position was held by the Caucasian colony. That colonies having the southeast, north-west, and northeast usually ranked below the southwest colony in this order respectively.

Table 13. The Drifting Factor[1] in the Quadruple Winter Case to the Colony receiving the Greatest Sun Exposure - Loss or Gain in Bees

Location	Colonies 33-36 1927-1928	Colonies 33-36 1928-1929	Colonies 33-36 1929-1930	Colonies 7-10 1929-1930
S.W.	-10.8 %	- 0.7 %	-74.5 %	-33.5 %
S.E.	-39.5 %	-30.5 %	-84.5 %	-27.1 %
N.W.	-42.9 %	-49.3 %	-60.3 %	Drone Layer
N.E.	-45.1 %	-59.4 %	-66.0 %	-44.3 %

[1]See also explanation of plate 10 for drifting in S.W.Colony 35 during the active season.

Modified Dadant Hives - 3 Colony Case

(See Table 22)

1927-1928. The six colonies numbered 37 to 42 were wintered in two 3-colony cases. The average amount of honey in these colonies in the fall was approximately 10 pounds, ranging from 7 lbs.-2 oz. to 13 lbs. This was supplemented by 34, 34, 34, 37.4, 27.2, and 34 pounds of sugar, respectively in numerical order. The fall records of colonies 37, 38, and 39 were taken September 25 which would account for the characteristic heavy loss of bees. However, colonies 37 and 42 being on the end and appreciably stronger in the fall were the only colonies of the group which survived the winter in good strength, proportional to their fall condition. In both groups the center colonies 38 and 41 survived the winter with only a small nucleus of bees remaining. Colony 40 on the north end of one case had only the queen and approximately 200 workers alive. This queen was apparently uninjured since she made a good showing when introduced into colony 55 (See plate 5). The consumption of stores was lower than found under other wintering methods, as should be expected from small colonies surviving. There is no reason, however, for attributing these poor results to the use of the Modified Dadant hives. It was undoubtedly a question of drifting.

1928-1929. Three colonies, 40, 41, and 42 were wintered in the 3-colony case during this season with results almost identical to the previous year. These colonies were fed 24, 18, and 24 pounds of sugar, respectively.

1-Story Hives - Cellar Wintering

(See Table 23)

1927-1928. Seven colonies, 43, 44, 45, 46, 52, 53, and 54 were placed in the cellar November 5 and removed on April 5. They were fed respectively in numerical order the following amounts of sugar, - 17, 34, 23.8, 23.8, 20.4, 13.6, and 20.4 pounds. The cellar wintered colonies consumed less stores than any of the outdoor group which is generally assumed to be a characteristic difference between the two general plans of wintering bees. The average loss of bees was greater than in the case of the quadruple pack but less than in the 3-colony case. However, the potential strength of the cellar colonies did not indicate as rapid spring advance as those wintered out of doors. It is probable that there were more over-wintering bees still in the clusters in early May and that brood-rearing had not advanced in the cellar wintered colonies. The united colony (48-51) was the only one to show favorable strength in early May. Furthermore, the weaker cellar colonies did not show any reserve strength for more rapid development than outdoor wintered colonies during May and June (See

plates 6 and 7).

1928-1929. Only two colonies, 12 and 23, were wintered in the cellar. Colony 12 received 6 pounds of sugar, and 23 received 18 pounds. These colonies consumed less stores than similar strength outdoor wintered colonies. On the other hand, colony 22 wintered in a double case had a strength in the spring identical to 23, yet consumed only 1 lb.-10 oz. more stores and had almost twice as many bees in the fall. While it was characteristic during this season for many colonies to show a substantial gain in bees, running as high as 46.6 per cent more than in the fall, the cellar colonies showed an average loss of 3.9 per cent.

1929-1930. Two colonies, 11 and 12, were prepared for cellar wintering, but 11 being quite strong with bees in the fall, began brood-rearing in early March and consumed more stores than is characteristic under cellar wintering. As a result, this colony starved to death with plenty of reserve honey set aside for spring brood-rearing. There was no evidence of dysentery being responsible for their early spring brood-rearing. Colony 12 consumed from 18 to 20 pounds less stores than those receiving no protection or the Top and Bottom pack and wintered out of doors while its strength the first of May was approximately only 40 to 85 per cent of these.

There can be no advantage in conserving stores under such a marked contrast in colony strengths.

Summary of Winter Methods

(See Table 24)

The combined summary of wintering for the three seasons indicates tendencies evident in the separate seasons. However, allowance should be made for the seasons represented, the number of colonies, the influence of early fall or late spring records, and for noticeably inferior queens. The colonies are ranked in the table in the order of their advantage in potential bees.

SUMMARY

1. The average number of bees per pound was found to vary between 2800 to 4800 due to differences in size of bees, proportion of young bees to field bees, drones to workers, the condition of the honey flow, the amount of honey in the hive, season of the year, and the temperament of the bees at the time of weighing.

2. 3500 to 4000 represents the average range in bees per pound for most colonies in contrast to the usually accepted 5000 which represents an approximate average for field bees.

3. The average weight of brood in pounds can be satisfactorily estimated by multiplying the average daily rate of brood-rearing by the constant .0042.

4. The brood nest is the center of all colony activity with a pronounced tendency toward an upward expansion. The latter is apparently the result of a temperature response.

5. The majority of brood in full strength colonies were sealed in 8 days and emerged 12 days after sealing. Variations in the length of the developmental stages occurred almost entirely in the unsealed stage. Brood which required 9, 10, or 11 days before sealing did not have the sealed stage correspondingly lengthened.

6. Brood-rearing normally takes place within the temperature range of 92.5° to 96.5° F. Brood areas

are so definitely defined by temperatures within the above range that a brood-rearing cluster may be considered as characteristic as the broodless winter cluster.

7. Brood-rearing may apparently be initiated by any condition resulting in the production of brood temperatures in the cluster as long as pollen and honey are both available for feeding. The reduction of brood-rearing may be as abrupt as its initiation.

8. Brood-rearing is a function of the colony and not of the queen alone.

9. The queen, when conditions are favorable for brood-rearing, has the capacity to reach from non-production, her maximum rate of egg-laying within less than a week. Sharp fluctuations in egg-laying by queens heading normal colonies seem unlikely.

10. The included observations substantiate those of other investigators working in widely separated geographic regions in the conclusion that regardless of the maximum daily rate of egg-laying, brood-rearing seldom exceeds an average daily rate of 1500 to 2000 cells of brood per day.

11. A colony containing 40,000 bees seems to provide the optimum strength for reaching the maximum rate of brood-rearing.

12. The colony containing 10,000 bees seems to have the optimum strength for obtaining the greatest amount of brood in proportion to the total number of

bees. The percentage ratio of sealed brood to total bees tends to decrease 12 per cent for each increase of 10,000 bees in colony strength.

13. A honey flow is not necessary for maximum brood-rearing. A heavy honey flow tends to reduce brood-rearing because the crowding of nectar into and around the brood nest reduces the number of cells available to the queen.

14. Daily feeding of thin sugar syrup to colonies well provided with stores does not stimulate them to a higher rate of brood-rearing. The evidence, while not marked, is consistent in showing a slight suppression of brood-rearing in such colonies.

15. Pollen is essential to brood-rearing. It is difficult to determine the amount of pollen available except in relative terms. It appears probable that the pollen supply may determine seasonal changes in brood-rearing during the active season more than any other external factor.

16. Swarm preparations tend to cause a reduction in brood-rearing. Continuous expansion by the colony in either brood-rearing or honey storage is not conducive to swarm preparations.

17. Caucasian and Carniolan queens made similar responses to factors governing brood-rearing as were made by Italian queens. There are no data

available at this time to support the contention that either of these races are more prolific than good Italian queens.

18. The double walled or Buckeye hive showed no beneficial or detrimental influence on brood-rearing. Neither is there any evidence that hive insulation is essential to efficient spring brood-rearing.

19. The worker population of normal colonies may vary from 10,000 to 70,000.

20. Colonies surviving the winter with 20,000 to 30,000 bees about two weeks before fruit bloom will be ready for a honey flow in three to four weeks under favorable conditions of development; those with 20,000 to 30,000, in five to eight weeks; while 2-pound packages will require eleven to twelve weeks from installation before reaching an equivalent strength.

21. The duration of life of bees in normal colonies may vary from 4 to 9 weeks; 6 weeks may be considered the normal length of life.

22. Bees die ~~s~~ at an earlier age in small colonies than in large ones. The rearing of proportionally large amounts of brood shortens the life of bees below that of bees in colonies where brood-rearing is less intense. Bees emerging prior to September 1, have little opportunity of surviving beyond the first of October or at the most beyond the end of brood-rearing. While the participation in a honey flow

tends to reduce the duration of life, its reduction is no greater if as great as that caused by intensive brood-rearing.

23. When the colony reaches its maximum strength, it tends to retain this until after the first of September provided that brood-rearing is not interrupted by a lack of pollen or honey, swarming, or by a failing queen.

24. Drifting proved to be an important problem having a direct bearing on both practical management and experimental studies on colony populations, duration of life, the evaluation of races or strains of bees, and on wintering methods.

25. The object of wintering is to conserve the energy of bees in order that the colony will have maximum potential capacity for brood-rearing when pollen and nectar become available in the spring; at the same time it is desirable to reduce the useless consumption of stores.

26. 20,000 to 30,000 bees which have emerged after September 1 are essential to the formation of an efficient winter cluster. The cluster itself provides the most efficient protection against loss of heat, essential in the conservation of bee energy.

27. The cluster maintains a surface temperature between 43° - 46° F. when outside temperatures are below freezing.

28. As the outside temperature lowers, the bees by contracting the cluster to reduce the surface exposed to radiation and by increasing the average temperature within, maintain the temperature at the surface just above the point where they would lose power of motion, with the minimum expenditure of energy.

29. The cluster by its formation of a compact surface "shell" of bees, possesses the remarkable capacity for preventing the rapid escape of heat. The cluster does not radiate heat to the unoccupied part of the hive, as a stove radiates heat to a room.

30. The entrance of the hive when reduced bears a similar relation to this unoccupied space as an open door does to a full sized room.

31. The value of wind protection and hive insulation in reducing the expenditure of bee energy is obtained through the reduction in the rate of temperature changes, thus permitting the cluster to adjust itself gradually; it is not obtained by the retention of heat radiated by the cluster.

32. Data from 77 colonies representing 12 different methods of wintering are summarized.

33. The loss of stores during the winter period is directly correlated with the strength of the colony in the spring (seasonal variations excluded),

indicating that the greatest portion of the stores consumed are used in spring brood-rearing before the colonies are removed from winter quarters.

34. Uninsulated colonies consume slightly more stores than moderately insulated colonies of equivalent strength.

35. Moderately insulated hives gave generally superior results during each of the three winter seasons studied.

36. There is a close inter-relationship between brood-rearing, colony development, and wintering. A proper understanding of these relationships will permit through management, a more efficient correlation of the colony's activities with its environment in order to provide a colony capable of maximum production during the occurrence of a honey flow or for the purpose of flower pollination.

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Table 6. Climatological Data, Amherst, Massachusetts
Monthly Summary - April 1927 to October 1930

Month	Temperature				Precipitation			Rel. Humidity		Hours Sunshine	
	Range		Mean		Inches			Per Cent		Per Cent Possible Hrs.	
	Max.	Min.	Month	Normal	Month	Normal	Snow	Month	Normal	Month	Normal
1927											
April	85	22	45.4	45.8	1.6	3.3	2	68.7	69.6	52	55
May	75	31	53.2	56.8	4.8	3.6		83.9	70.7	30	55
June	89	37	62.4	63.7	3.4	3.5		80.2	73.9	44	56
July	91	43	69.6	70.6	3.4	4.3		88.8	75.6	45	58
Aug.	83	44	64.6	68.4	5.0	4.2		87.3	78.4	46	55
Sept.	85	34	60.6	61.6	2.8	3.8		89.0	80.0	62	54
Oct.	89	24	53.5	50.4	4.6	3.3		85.3	76.9	63	50
Nov.	70	20	44.0	38.6	8.6	3.4		84.3	76.3	22	41
Dec.	62	8	29.5	27.3	5.7	3.5	3	81.3	77.2	35	46
1928											
Jan.	54	- 4	27.7	24.1	2.2	3.4	4	78.9	78.2	44	48
Feb.	51	- 4	25.7	23.5	2.9	3.3	8	77.2	77.9	56	54
Mar.	68	8	32.9	34.2	1.2	3.7	12	80.2	75.0	58	54
April	83	20	42.6	45.8	4.2	3.3	2	76.8	69.6	58	55
May	81	31	55.0	56.8	3.3	3.6		77.1	70.7	50	55
June	85	41	63.1	63.7	7.0	3.5		82.6	73.9	37	56
July	93	47	71.5	70.6	6.2	4.3		80.6	75.6	54	58
Aug.	92	52	70.6	68.4	8.4	4.2		86.3	78.4	47	55
Sept.	84	31	57.8	61.6	3.1	3.8		85.2	80.0	48	54
Oct.	86	19	51.1	50.4	.9	3.3		79.2	76.9	49	50
Nov.	73	14	39.4	38.6	1.0	3.4	2	78.1	76.3	42	41
Dec.	56	8	31.6	27.3	1.0	3.5	T	77.0	77.2	48	46

Table 6. Climatological Data, Amherst, Massachusetts
Monthly Summary - April 1927 to October 1930

(Continued 2)

Month	Temperature: Range Max.	Range Min.	Mean Month	Mean Normal	Precipitation (Inches): Month	Normal	Snow	Rel. Humidity (Per Cent): Month	Normal	Hours Sunshine (Per Cent Possible Hrs.): Month	Normal
1929											
Jan.	56	-11	22.8	24.1	4.3	3.4	18	71.1	78.2	47	48
Feb.	54	- 1	25.5	23.5	3.9	3.3	15	77.3	77.9	46	54
March	67	3	37.8	34.2	3.2	3.7	5	71.3	75.0	42	54
April	87	22	45.2	45.8	6.9	3.3	6	69.0	69.6	35	55
May	92	31	56.6	56.8	4.2	3.6		60.8	70.7	53	55
June	92	35	67.1	63.7	3.1	3.5		66.3	73.9	55	56
July	94	45	70.1	70.6	.7	4.3		66.0	75.6	51	58
Aug.	90	41	66.5	68.4	1.5	4.2		65.0	78.4	35	55
Sept.	97	33	63.1	61.6	3.6	3.8		72.4	80.0	47	54
Oct.	76	22	49.0	50.4	2.8	3.3		64.0	76.9	55	50
Nov.	74	7	39.6	38.6	2.7	3.4	3	71.4	76.3	41	41
Dec.	46	1	28.1	27.3	4.1	3.5	8	76.0	77.2	33	46
1930											
Jan.	56	- 4	26.0	24.1	2.6	3.4	10	74.1	78.2	40	47
Feb.	65	- 6	29.2	23.5	3.4	3.3	6	66.9	77.9	61	54
March	56	14	35.0	34.2	3.9	3.7	T	61.6	75.0	64	54
April	75	25	44.1	45.8	1.4	3.3	T	59.0	69.6	68	55
May	92	35	59.1	56.8	3.4	3.6		60.8	70.7	63	55
June	92	37	70.6	63.7	4.5	3.5		69.1	73.9	69	56
July	95	46	69.9	70.6	4.5	4.3		70.4	75.6	65	58
Aug.	93	43	67.8	68.4	1.8	4.2		71.6	78.4	65	55
Sept.	88	35	64.0	61.6	2.1	3.8		74.8	80.0	65	54

Table 7. Colony Development Data, 1927

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio Of Sealed Brood To Total Bees	Pounds Honey
19	May 5				7,810		
	" 19				14,470		
	" 29	6 - 6 oz.	4000	25,500	18,750	73.5	14 - 12 oz.
	June 10				6,303		
	" 22	12	4000	48,000	11,080	23.1	54 - 2
	July 4				13,290		
	" 16	10 - 14	3555	38,558	13,560	35.2	56 - 14
	" 27				11,180		
	Aug. 5	11 - 8	4000	46,000	11,010	23.9	41 - 4
	" 17				12,250		
	" 31	11 - 4	3900	43,875	11,430	26.0	21 - 12
	Sept.12				12,330		
	" 24	10 - 2	4000	40,500	10,680	26.2	16 - 15
20	May 5				8,470		
	" 19				15,780		
	" 29	5 - 6 oz.	3600	19,350	17,760	91.8	14 - 3 oz.
	June 10				16,630		
	" 22	10 - 2	4000	42,000	15,560	38.4	39 - 5
	July 4				10,770		
	" 16	11 - 6	4000	45,500	9,563	21.0	40 - 14
	" 27				14,910		
	Aug. 5	11 - 10	4000	46,500	15,020	32.3	30 - 8
	" 17				14,000		
	" 31	13	4000	52,000	10,880	20.9	11 - 6
	Sept.12				12,250		
	" 24	10 - 4	4357	44,660	6,370	14.2	11 - 7

Table 7. Colony Development Data, 1927 (Cont. 2)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
53	May 5				7,041		
	" 17				8,194		
	" 29	4 - 2 oz.	3555	14,664	11,130	75.9	8 - 13 oz.
	June 10				7,973		
	" 22	6 - 2	3555	22,274	7,290	33.5	22 - 12
	July 4				4,713		
	" 16	5 - 10	4000	22,500	13,860	61.6	52 - 13
	" 27				12,630		
	Aug. 5	8 - 14	4000	35,500	13,810	38.9	40 - 12
	" 17				12,390		
	" 31	14 - 4	4000	57,000	11,150	19.6	17 - 3
	Sept.12				13,860		
	" 24	8 - 14	3563	36,130	3,398	9.4	25 - 6
54-47	May 5				9,263		
	" 17				16,060		
	" 29	7 - 2 oz.	3555	25,329	15,130	59.7	8 - 9 oz.
	June 10				10,830		
	" 22	7 - 2	4000	28,500	12,850	45.2	28 - 14
	July 4				13,840		
	" 16	10 - 6	3430	35,590	14,170	39.8	38 - 7
	" 27				10,090		
	Aug. 5	9 - 12	4000	39,000	11,210	28.7	30 - 15
	" 17				11,590		
	" 31	11 - 14	3717	50,467	12,170	24.1	10
	Sept.12				12,220		
	" 24	7 - 12	3225	24,993	7,673	30.7	6 - 11

Table 7. Colony Development Data, 1927 (Cont.3)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
29	May 18				6,576		
	" 30				6,960		
	June 11				9,097		
	" 23	6 - 8 oz.	3200	20,800	11,260	54.1	15 - 8 oz.
	July 5				10,770		
	" 18	12 - 4	3200	39,200	6,878	17.5	58 - 5
	" 30				5,316		
	Aug. 11	12 - 12	3555	45,324			53 - 14
	" 25				4,193		
	Sept. 6	13 - 14	3598	49,924	12,030	24.1	39 - 2
	" 20				14,630		
	Oct. 8	8 - 4	3474	28,660			55 - 5
30 Package	May 18				11,650		
	" 30				10,690		
	June 11				12,300		
	" 23	7 - 6 oz.	4000	29,500	13,460	45.6	19 - 2 oz.
	July 5				18,580		
	" 18	13 - 14	3200	44,400	16,330	36.8	59 - 10
	" 30				14,470		
	Aug. 11	16 - 2	4000	64,500	14,660	22.7	42 - 10
	" 25				10,690		
	Sept. 7	15 - 8	4900	75,950	13,320	17.5	18 - 7
	" 20				8,878		
	Oct. 8	6 - 14	3580	24,616	411		39 - 10

Table 7. Colony Development Data, 1927 (Cont. 4)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
31	May 18				8,795		
Package	" 30				2,712		
installed	June 11				9,152		
April 29	" 23	3 - 12 oz.	4000	15,000	12,250	81.7	10 - 3 oz.
	July 5				16,630		
	" 18	8 - 8	3660	31,158	14,690	47.1	38 - 4
	" 30				13,890		
	Aug. 11	12 - 6	4000	49,500	14,360	29.0	29 - 3
	" 25				13,370		
	Sept. 6	14 - 8	4571	66,265	13,460	20.3	14 - 10
	" 20				9,700		
	Oct. 8	6 - 14	3480	23,925			35 - 6
32	May 18				8,825		
Package	June 11				4,165		
	" 23	2 - 8 oz.	3555	8,887	10,060	113.1	7 - 5 oz.
	July 5				15,180		
	" 18	6 - 12	4000	27,000	14,180	52.5	30 - 6
	" 30				13,120		
	Aug. 11	11 - 0	3555	39,105	12,030	30.8	19 - 12
	" 25				9,920		
	Sept. 6	10 - 0	4923	49,230	12,630	25.6	7 - 4
	" 20				9,727		
	Oct. 8	5 - 11	3175	18,075	767		19 - 9

Note: Pounds of honey in this and tables 8, 9, and 10 equals the amount in the hive when determinations were made - does not indicate amount fed or removed.

Table 8. Colony Development Data, 1928

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
56	May 2	5 - 4 oz.	3652	19,173	4,823	25.2	11 - 14 oz.
	" 14				4,576		
	" 27	3 - 11	4011	14,783	14,440	97.7	11 - 5
	June 8				11,510		
	" 23	7 - 1	4482	31,654	14,220	42.9	7 - 0
55	Young bees and sealed brood from 56; queen from robbed Dadant Colony 40 (May 3)						
	May 14				7,070		
	" 27	4 - 5 oz.	4324	18,646	10,390	55.7	15 - 12 oz.
	June 8				13,560		
	" 23	9 - 10	4271	41,129	15,350	37.3	5 - 7
55 & 56	May 2				4,823		
	" 14				11,646		11 - 14 oz.
	" 27			33,429	24,830		27 - 1
	June 8				25,070		
	" 23			72,783	29,570		12 - 7

Table 8. Colony Development Data, 1928 (Cont. 2)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
57	May 2	7 - 3 oz.	4142	29,774	7,343	24.7	13 - 11 oz.
	" 14				7,125		
	" 27	6 - 2	4272	26,166	19,070	72.8	14 - 1
	June 8				16,170		
	" 23	10 - 10	4540	48,140	17,190	35.7	2 - 14
58	May 3	Young bees and sealed brood from 57; young queen.					
	" 14				5,672		
	" 27	4 - 7.5 oz.	3821	17,069	8,331		12 - 8 oz.
	June 8				13,070		
	" 23	8 - 3	4334	35,485	13,050		5 - 0
57 & 58	May 2			29,774	7,343		13 - 11
	" 14				12,797		32 - 3
	" 27			43,235	27,410		26 - 9
	June 8				29,240		
	" 23			83,625	30,240		7 - 14

Table 8. Colony Development Data, 1928 (Cont. 3)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
24	May 2	5 - 12 oz.	4416	25,392	3,290	12.9	10 - 6 oz.
	" 14				10,580		
	" 27	5 - 2	4563	23,385	15,150	64.8	9 - 4
	June 8				14,930		
	" 23	8 - 6	4562	38,206	13,340	34.8	4 - 13
1	May 3	5 - 2 oz.	4146	21,250	3,754	17.7	17 - 3 oz.
	" 15				14,470		
	" 27	7 - 14	3914	30.828	18,610	60.4	13 - 15
	June 10				16,800		
	" 23	10 - 8	4607	48,374	16,420	33.9	9 - 8
2	May 3	6 - 6.5 oz.	4054	25,969	4,686	18	8 - 13 oz.
	" 15				15,130		
	" 28	8 - 14	4279	37,977	15,920	41.9	17 - 5
	June 10				15,540		
	" 23	10 - 15	4457	48,748	17,460	35.8	10 - 2
46	May 3	2 - 5 oz.	3815	8,725	2,000	22.9	7 - 6 oz.
	" 15				9,562		
	" 28	3 - 10	4106	14,883	12,170	81.7	1 - 15
	June 10				6,700		
	" 23	6 - 4	4908	30,673	11,290	36.8	1 - 1

Table 8. Colony Development Data, 1928 (Cont. 4)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
19	May 3	4 - 13 oz.	3533	17,005	4,220	24.8	25 - 0 oz.
	" 17				8,523		
	" 29	6 - 1	3730	22,613	10,910	48.2	27 - 1
	June 10				9,508		
	" 26	7 - 5	4034	29,498	5,261		16 - 1
20	May 5	7 - 15 oz.	3783	30,021	4,165	13.9	14 - 0 oz.
	" 17				15,780		
	" 29	9 - 13	3903	38,299	20,140	52.6	20 - 5
	June 10				15,970		
	" 25	6 - 9	4230	27,756	8,906		5 - 6
*29	May 5	9 - 2 oz.	3857	35,195	5,645	16.0	9 - 4 oz.
	" 17				15,860		
	" 29	11 - 7	3960	45,296	17,620	38.9	26 - 2
	June 10				15,150		
	" 26	12 - 5	3936	47,232	7,591		5 - 8
12	June 26	7 - 7 oz.	4078	30,331	5,426		4 - 6 oz.

*Note: June 11, 1928 moved to position 12. Brood of 30 placed here, introduced Caucasian queen.

Table 8. Colony Developmant Data, 1928 (Cont. 5)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
30	May 5	6 - 1.5 oz.	4012	24,448	3,453	14.1	8 - 9 oz.
	" 17				16,360		
	" 29	8 - 8	3902	33,167	19,760	59.6	11 - 14
	June 10				16,910		
	" 26	9 - 4	4271	39,502	10,440		8 - 2

Note: Brood of 30 moved to 29 position.

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
43	May 5	4 - 5 oz.	3989	16,081	3,892	24.2	8 - 13 oz.
	" 17				8,445		
	" 29	4 - 14	3751	18,287	Queenless		14 - 6
44	May 5	2 - 7.5 oz.	3541	8,740	2,302	26.3	12 - 12 oz.
	" 17				10,220		
	" 29	2 - 14	3943	11,337	9,262	81.7	17 - 10
	June 10				8,194		
	" 25	5 - 9	4331	24,094	10,030	41.6	2 - 11

Note: United Colony 43, May 29.

Table 8. Colony Development Data, 1928 (Cont. 6)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
45	May 5	1 - 1.5 oz.	4243	4,640	1,041	22.4	10 - 7 oz.
	" 17				3,672		
	" 29	2 - 3	3618	7,914	5,783	73.1	4 - 10
	June 10				6,137		
	" 25	3 - 4	4112	13,364	3,453		3 - 3
49	May 5	4 - 12.5 oz.	3989	19,081	3,810	20.0	6.- 11 oz.
	" 17				15,320		
	" 29	7 - 2	4046	28,828	19,270	66.8	15 - 8
	June 10				13,620		
	" 25	8 - 14	4707	41,772	10,030	24.0	0 - 2
52	May 6	1 - 12.5 oz.	3874	6,899	1,343	19.5	5 - 2 oz.
	" 21				9,070		
	" 30	2 - 8	4643	11,607	10,550	90.9	3 - 0
	June 12				10,090		
	" 25	5 - 13	4017	23,348	11,350	48.6	2 - 4
53	May 6	4 - 3 oz.	3771	15,792	2,823	17.9	7 - 0 oz.
	" 21				13,840		
	" 30	5 - 0	4237	21,185	14,060	66.5	7 - 3
	June 12				8,714		
	" 25	8 - 7	4462	37,656	12,330	32.7	3 - 2

Table 8. Colony Development Data, 1928 (Cont. 7)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
54	May 6	5 - 6 oz.	4231	22,739	5,131	22.7	4 - 10 oz.
	" 21				14,690		
	" 30	7 - 1	3905	27,579	16,220	58.8	12 - 7
	June 12				15,050		
	" 25	10 - 7	4540	47,388	12,990	27.4	5 - 2
50	May 5	2 - 0 oz.	4300	8,600	493	5.4	9 - 8 oz.
	" 17				6,440		
	" 29	2 - 7	4257	10,430	9,618	92.2	4 - 14
	June 10				7,747		
	" 25	4 - 14	4390	21,396	8,054	37.6	4 - 3
31	May 5	6 - 3.5 oz.	4127	25,732	3,370	13.1	9 - 5 oz.
	" 21				14,930		
	" 30	6 - 14	4424	30,415	17,210	56.6	9 - 13
	June 12				14,720		
	" 27	8 - 11	3725	32,363	7,591	23.5	8 - 2
32	May 6	2 - 14.5 oz.	3848	11,176	2,083	18.6	11 - 5 oz.
	" 21				13,670		
	" 30	4 - 7	4265	18,922	15,700	83.0	13 - 12
	June 12				15,120		
	" 27	8 - 8	4461	37,918	13,370	35.3	5 - 0

Table 8. Colony Development Data, 1928 (Cont. 8)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
41	May 8	1 - 5.5 oz.	3214	4,320	1,562	36.2	12 - 8 oz.
	" 21				9,839		
	June 1	3 - 1.5	3895	12,049	9,785	81.2	8 - 10
	" 12				11,050		
	" 27	5 - 13	4340	25,223	9,645	38.2	1 - 7
42	May 10	3 - 7 oz.	4295	14,761	5,590	37.9	12 - 1 oz.
	" 22				12,440		
	June 1	7 - 9.5	4105	31,177	16,470	52.8	7 - 1.5
	" 12						
	" 27	5 - 6	4069	21,896	9,785		4 - 15
Note: Removed brood June 12 = 15,070							
33	May 9	3 - 11.5 oz.	4061	15,104	6,111	40.5	8 - 7 oz.
	" 22				14,790		
	June 1	7 - 7	4554	33,873	17,260	51.0	6 - 15
	" 13				15,400		
34	May 9	3 - 14.5 oz.	3517	13,741	5,783	42.1	8 - 3 oz.
	" 22				13,650		
	June 2	7 - 9	4496	34,001	17,760	52.2	5 - 0
	" 13				9,460		

Table 8. Colony Development Data, 1928 (Cont. 9)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio Sealed Brood to Total Bees	Pounds Honey
35	May 9	8 - 2 oz.	4050	32,906	8,824	26.8	11 - 5 oz.
	" 22				15,700		
	June 2	9 - 6	4214	39,494	24,060	60.9	8 - 8
	" 13				Brood 20		
	" 27	12 - 8	4375	54,688	14,230		6 - 10

Note: June 11 Brood 35 to 14 position = 16,830 June 13.

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio Sealed Brood to Total Bees	Pounds Honey
36	May 9	4 - 4.5 oz.	3777	16,170	8,411	52.0	7 - 15 oz.
	" 22				15,100		
	June 2	8 - 6.5	4131	34,725	15,350	44.2	8 - 5
	" 13				13,780		
	" 26	11 - 1	4305	47,625	13,650	28.7	5 - 4
*37	May 8	5 - 14.5 oz.	3388	20,014	6,686	33.4	13 - 1 oz.
	" 21				14,600		
	June 1	7 - 0	3930	27,510	15,730	57.2	6 - 4
	" 12				15,070	(Brood of 42)	
	" 27	7 - 0	3959	27,713	12,610		1 - 2
40	June 27	8 - 2 oz.	3960	32,175	1,836		

*Note: Exchanged position with Colony 38 May 10 - Data of original Colony 37.
Colony moved to location 40, June 11; contained 14,880 Sealed Brood June 12.

Table 8. Colony Development Data, 1928 (Cont. 10)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
38	May 10	1 - 0 oz.	3408	3,408	932	27.3	17 - 5 oz.
	" 22				7,947		
	June 1	3 - 6	3648	12,312	11,590	94.2	11 - 2
	" 12				13,810		
	" 27	8 - 4	4118	33,973	8,895	25.9	4 - 6

Note: Exchanged position with Colony 37 May 10 - Data of original Colony 38.

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
39	May 8	2 - 6.5 oz.	4320	10,395	3,480	33.5	16 - 6 oz.
	" 21				10,690		
	June 1	4 - 10.5	3755	17,488	11,620	66.4	5 - 6
	" 12				13,430		
	" 27	9 - 8	4273	40,594	15,240	29.8	1 - 9

Table 9. Colony Development Data, 1929

Colony	Date		Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
1	May	6	6 - 5.5 oz.	4039	25,525	13,150	51.5	20 - 12 oz.
2	"	5	6 - 4	3273	20,456	6,605	32.3	23 - 3
3	"	6	4 - 10	4089	18,911	9,950	52.6	10 - 0
4	"	5	1 - 7	3772	5,424	(Queenless)		14 - 1
11	"	6	4 - 9	4387	20,014	12,170	60.8	7 - 14
12	"	5	4 - 5.5	3691	15,034	8,712	58.0	6 - 1
13	"	6	3 - 3.5	3812	12,276	9,920	80.8	8 - 14
14	"	5	5 - 8.5	3615	19,996	11,650	58.2	14 - 11
20	"	6	5 - 11.5	4129	23,601	12,250	51.9	18 - 7
21	"	5	2 - 2	3798	8,071	5,536	68.6	9 - 1
22	"	6	2 - 10	3607	9,469	7,098	75.0	15 - 2
23	"	6	2 - 8	3630	9,075	7,674	84.6	7 - 12
29	"	5	7 - 3	3446	24,767	15,400	62.2	17 - 3
30	"	6	4 - 12	4021	19,099	5,645	29.6	22 - 15
31	"	5	6 - 4.5	3514	22,074	10,250	46.4	10 - 3
33	"	7	1 - 9	3720	5,817	3,810	65.5	17 - 1
34	"	7	2 - 12	3839	10,558	9,125	86.4	16 - 5
35	"	7	6 - 7	3713	23,902	11,240	47.0	23 - 0
36	"	7	3 - 1	4030	12,342	10,390	84.2	7 - 2
40	"	6	2 - 3.5	3647	8,092	6,137	75.9	33 - 1
41	"	6	1 - 10	3537	5,747	5,152	88.8	12 - 13
56	"	5	6 - 13	2821	19,214	8,470	44.1	21 - 6
57	"	5	6 - 8	3209	20,858	9,755	46.8	24 - 11
58	"	6	2 - 11	3896	10,476	9,150	87.3	19 - 0

Table 9. Colony Development Data (Cont. 2)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
7	July 27	11 - 13 oz.	3612	42,670	12,300	28.8	109 - 1 oz.
	Aug. 8				7,948		
	" 20	11 - 11.5	4041	47,360	5,618		48 - 6.5
	Sept. 2				12,250		
	" 16	7 - 14.5	4271	33,769	10,140	30	22 - 13
	" 30				5,180		
	Oct. 5	8 - 2.5	4065	33,143	3,042		18 - 15.5
19	July 27	8 - 7 oz.	4176	35,235	11,400	32.4	25 - 14 oz.
	Aug. 8				7,685		
	" 20	10 - 2.5	4203	42,687	5,645		10 - 6.5
	Sept. 2				10,110		
	" 16	7 - 2	4322	30,794	5,316	17.6	16 - 15
	" 30				466		
	Oct. 4	6 - 0	4177	25,062			13 - 12
35	July 27	9 - 6	3772	35,364	7,563		28 - 12
	Aug. 8				4,220		
	" 20	9 - 13	3797	37,384	6,850	18.3	26 - 1
	Sept. 2				12,110		
	" 16	9 - 6	4215	38,989	7,070	18.1	39 - 11
	" 30				823		
	Oct. 4	8 - 2	4128	33,540			23 - 1.5

Table 9. Colony Development Data, 1929 (Cont. 3)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
55	July 29	12 - 1 oz.	3845	46,480	10,440	22.5	46 - 6 oz.
	Aug. 10				6,796		
	" 22	12 - 4	3688	45,178	13,730	30.4	29 - 15
	Sept. 3				11,210		
	" 16	11 - 10.5	3810	44,430	11,130	25	21 - 7
	" 30	(2 frames containing immature stages)			475		
	Oct. 6	8 - 8	4416	37,536			12 - 8.5
56	July 29	13 - 14 oz.	3430	44,586	10,170	22.8	151 - 10 oz.
	Aug. 10				5,891		
	" 22	12 - 1.5	3758	45,448	12,850	28.3	29 - 0
	Sept. 3				9,042		
	" 16	11 - 3	4282	47,906	6,715		23 - 6
	" 30	(No sealed brood. 2 frames containing immature forms, mostly eggs)					
	Oct. 6	7 - 13.5	4296	33,865			21 - 6
57	July 29	12 - 9 oz.	3915	49,176	9,097	18.5	113 - 11 oz.
	Aug. 10				2,987		
	" 22	12 - .5	4028	48,452	3,563		62 - 1
	Sept. 3				9,509		
	" 16	11 - 11	4036	47,168	7,700	16.3	52 - 7
	" 30	(2 frames containing eggs)			1,510		
	Oct. 6	11 - 8.5	3795	43,759			42 - 15

Table 9. Colony Development Data, 1929 (Cont. 4)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
58	July 29	11 - 4 oz.	3823	42,009	12,280	29.2	92 - 3 oz.
	Aug. 10				5,783		
	" 22	11 - 6	4086	46,476	7,343		30 - 1
	Sept. 3				11,810		
	" 16	11 - 3.5	4087	45,853	8,795	19.2	24 - 4
	" 30	(Few eggs)			1,400		
	Oct. 6	8 - 13	4288	37,788			19 - 3.5
59	July 29	9 - 0 oz.	3353	30,177	10,770	35.7	134 - 3 oz.
	Aug. 10				7,727		
	" 22	8 - 15	4086	36,513	6,576		49 - 7
	Sept. 3				11,130		
	" 20				2,025		
	" 30				218		
60	July 29	4 - 15 oz.	4040	19,955	9,482	47.5	105 - 9 oz.
	Aug. 10				6,686		
	" 22	6 - 9	4182	27,441	13,510	49.2	50 - 9
	Sept. 3				11,150		
	" 16	8 - 1	4412	35,572	7,290	20.5	42 - 6
	" 30				1,040		

Table 9. Colony Development Data, 1929 (Cont. 5)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
1	Aug. 1	12 - 9 oz.	3909	49,104	11,130	22.7	198 - 0 oz.
	" 13				7,041		
	" 23	8 - 8.5	4504	38,429	8,411		39 - 11
	Sept. 4				10,220		
	" 17	8 - 8	4466	37,961	7,755	20.4	35 - 11
	" 30	(Few eggs and young larvae in one frame)			1,150		
	Oct. 4	6 - 15	4191	29,075			28 - 7
2	Aug. 1	7 - 7 oz.	4330	32,207	9,730	30.2	101 - 3 oz.
	" 13				5,344		
	" 23	9 - 1.5	4535	41,241	7,125		51 - 2
	Sept. 4				12,090		
	" 18	9 - 10.5	4095	39,543	9,016	22.8	40 - 12
	Oct. 5	8 - 14.5	3974	35,388	383		26 - 8.5
29	Aug. 1	12 - 8 oz.	4138	51,725	6,137		163 - 7 oz.
	" 13				6,330		
	" 23	11 - 1.5	4359	48,357	8,604		27 - 2
	Sept. 4				9,730		
	" 17	8 - 8.5	4347	37,084	7,371	19.9	21 - 8
	Oct. 5	7 - 14.5	3890	30,797	493		18 - 3

Table 9. Colony Development Data, 1929 (Cont. 6)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
30	Aug. 1	10 - 6 oz.	3809	39,518	14,600	37.0	122 - 10 oz.
	" 13				8,960		
	" 23	11 - 4.5	4002	45,047	8,665		20 - 14
	Sept. 4				11,100		
	" 18	9 - 13	4179	41,004	8,580	20.9	13 - 2
	Oct. 4	7 - 14.5	4445	35,134	575		11 - 7
21	Aug. 1	6 - 7 oz.	3920	25,235			12 - 13 oz.
	" 13				2,686		
	" 23	3 - 14.5	4510	17,629	10,500	59.5	8 - 10
	Sept. 4				5,837		
	" 18	5 - 2	4208	21,566	3,344	15.5	5 - 2
	" 18	(21 & 21B united)		39,714	3,344		
	Oct. 5	5 - 9.5	4103	22,947	959		24 - 0
21 B	Aug. 1	3 - 4 oz.	3808	12,376	10,220		48 - 8 oz.
	" 13				3,014		
	" 23	5 - 1	4121	20,605	0		36 - 7
	Sept. 4				0		
	" 18	4 - 4.5	4239	18,148			33 - 3.5

Table 9. Colony Development Data, 1929 (Cont. 7)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
22	Aug. 1	3 - 9 oz.	4138	14,745	0		21 - 13 oz.
	" 13				0		
	" 23	2 - 1	4180	8,633	6,986	81	18 - 3
	Sept. 4				5,783		
	" 18	4 - 5	4156	17,924	8,331	46.5	9 - 7
23	Aug. 1	4 - 14 oz.	3611	17,608	15,970	52	43 - 10 oz.
(22B)	" 13				10,130		
	" 23	8 - 3	4508	36,910	14,200	38.5	29 - 3
	Sept. 4				10,280		
	" 18	9 - 4	4357	40,302	7,535	18.3	20 - 7
	Oct. 4	7 - 15	3985	31,630	2,055		16 - 14

Table 10. Colony Development Data, 1930

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
1	May 1	4 - 10.5 oz.	4131	19,224	9,950	51.5	28 - 13 oz.
2	" 1	7 - 0.5	4095	28,814	13,840	48.0	11 - 8
3	" 2	9 - 1.0	3984	36,102	14,310	39.6	23 - 9
4	" 2	8 - 11.0	3902	33,900	15,730	46.4	22 - 5
8	" 1	6 - 6.5	3767	24,129	10,985	45.5	19 - 6
9	" 1	5 - 3	3974	20,620	11,780	57.1	24 - 1
10	" 2	6 - 5	4103	25,868	7,920	30.6	23 - 2
13	" 2	4 - 15.5	3170	15,751	11,810	74.8	20 - 4
14	" 2	6 - 8	4126	26,819	12,220	49.3	15 - 10
30	" 1	6 - 9.5	4104	27,056	12,630	46.7	24 - 9
33	" 1	3 - 11.5	3964	14,744	7,480	50.7	26 - 5
34	" 1	3 - 14.5	3624	14,149	8,301	58.7	22 - 5
36	" 2	1 - 15	3413	6,612	2,193	33.2	24 - 4
55	" 2	5 - 15	3920	23,275	14,550	62.5	21 - 10
6	May 1	4 - 5.5 oz.	4448	19,321	9,952	51.5	19 - 3 oz.
	" 7				All Brood Removed		All Honey Removed
	June 10	4 - 4.5	4754	20,341	10,030	49.3	2 - 11
	" 23	6 - 3	4553	28,173	17,380	61.7	10 - 11
	July 5	7 - 7	4621	34,370	16,990	49.4	12 - 11
	" 17	9 - 7.5	4682	44,335	15,860	35.8	9 - 3
	" 29	11 - 0.5	4231	46,673	10,715		12 - 7
	Aug. 10	10 - 6.5	3727	38,856	4,767		19 - 1
	" 22	9 - 11	3977	38,532	3,617		14 - 11
	Sept. 3	9 - 5	4386	40,844	5,620		11 - 6
	" 15	8 - 9	4265	36,514	13,890	38.1	12 - 9
	" 27	9 - 9.5	3585	34,383	6,386		16 - 11

Table 10. Colony Development Data, 1930 (Cont. 2)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
12	May 1	4 - 3.5 oz.	3767	15,890	8,331	52.4	37 - 8 oz.
	" 22				15,180		
	June 10	10 - 15.	4607	50,389	9,290	18.4	35 - 9
	" 23	11 - 15	3795	45,300	7,891	17.4	42 - 5
	July 5	10 - 9.5	4036	42,754	9,100	21.3	42 - 10
	" 17	9 - 13	3898	38,254	7,947		38 - 0
	" 29	11 - 11	3585	41,899			36 - 4
	Aug. 10	10 - 3	3514	35,800	11,160		41 - 14
	" 22	10 - 13.5	3739	40,549	19,780	48.8	33 - 11
	Sept. 3	12 - 9.5	4114	51,810	16,660	32.2	28 - 1
	" 15	12 - 8.5	3863	48,404	13,760	28.4	28 - 2
	" 27	9 - 13.5	3819-	37,597	6,490		32 - 8
	Oct. 9	8 - 0.5	3743	30,061	603		24 - 2
19	May 1	3 - 9 oz.	4028	14,352	8,140	56.7	28 - 9 oz.
Cau-	" 22				14,200		
casian	June 10	7 - 15.5	4148	33,054	15,810	47.9	53 - 13
	" 23	11 - 1	3685	40,765	14,580	35.8	58 - 9
	July 5	10 - 6.5	4014	41,771	15,500	39.5	58 - 4
	" 17	11 - 7	4282	48,985	14,990	30.6	54 - 2
	" 29	11 - 15.5	3966	47,468	14,090	29.7	52 - 6
	Aug. 10	11 - 9.5	4036	46,790	14,310	30.6	57 - 14
	" 22	11 - 6.5	4206	47,976	13,510	28.1	51 - 7
	Sept. 3	12 - 9	3730	46,857	14,440	30.8	47 - 10
	" 15	10 - 13	3951	42,721	9,206	21.6	51 - 8
	" 27	8 - 8	3752	31,892	4,548		57 - 8
	Oct. 9	5 - 12.5	3783	21,865	493		40 - 0

Table 10. Colony Development Data, 1930 (Cont. 3)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
20	May 1	6 - 13.5 oz.	3836	26,256	12,770	48.6	12 - 7 oz.
	" 22				17,480		
	June 10	11 - 2	3694	41,096	17,350	42.2	29 - 14
	" 23	16 - 13	3730	62,709	14,440	23.0	36 - 1
	July 5	14 - 0.5	4406	61,821	15,480	25.0	36 - 15
	" 17	15 - 1	4038	60,822	11,590		31 - 4
	" 29	16 - 6	3819	62,538	3,152		29.- 7
	Aug. 10	12 - 9.5	3690	46,475	15,350	33.0	36 - 8
	" 22	13 - 0.5	3798	49,492	18,450	36.4	28 - 0
	Sept. 3	14 - 5	3896	55,759	16,580	29.7	23 - 12
	" 15	11 - 15	3898	46,532	12,300	26.5	24 - 13
	" 27	9 - 14.5	3552	35,187	5,783		27 - 11
	Oct. 9	6 - 11.5	3888	26,123			22 - 10
23	May 1	6 - 14 oz.	4120	28,225	14,410	51.1	17 - 2 oz.
	" 22				15,370		
	June 10	10 - 10	3940	41,850	15,020	35.9	36 - 12

Table 10. Colony Development Data, 1930 (Cont. 4)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
29	May 2	2 - 8 oz.	3992	9,980	8,301	83.2	33 - 7 oz.
	" 22				13,590		
	June 10	8 - 7	4044	34,143	12,690	39.2	43 - 12
	" 23	9 - 11.5	3922	38,115	11,510	30.2	51 - 5
	July 5	9 - 5	3771	35,119	12,410	35.4	52 - 14
	" 17	9 - 11	3928	38,047	7,208		48 - 7
	" 29	9 - 14.5	3891	38,543	959		46 - 14
	Aug. 10	7 - 4	3686	26,723	1,206		51 - 0
	" 22	6 - 1	4076	24,711	13,860	56.1	47 - 0
	Sept. 3	7 - 14.5	4063	32,124	11,180	34.8	42 - 10
	" 15	8 - 12	3980	34,825	10,990	31.5	42 - 8
	" 27	8 - 2	3858	31,346	2,304		45 - 2
	Oct. 9	5 - 4.5	4148	21,910			38 - 1
35	May 1	2 - 4 oz.	3803	8,557	3,344	39.1	31 - 9 oz.
Cau-	" 22				15,480		
casian	June 10	9 - 2	4144	37,814	13,890	36.7	31 - 5
	" 23	11 - 13.5	3582	42,436	12,390	29.2	41 - 1
	July 5	11 - 15	3688	44,018	16,770	38.0	41 - 11
	" 17	13 - 1	4120	53,818	10,630		35 - 10
	" 29	16 - 1	3511	56,396	438		29 - 4
	Aug. 10	11 - 4.5	4046	45,644	16,960	37.2	46 - 3
	" 22	13 - 11.5	4177	57,301	17,350	30.3	35 - 3
	Sept. 3	15 - 1.5	3730	56,299	16,630	29.5	31 - 12
	" 15	15 - 2.5	3918	59,382	13,430	22.6	35 - 11
	" 27	11 - 6	3393	38,595	10,110		43 - 6
	Oct. 9	8 - 8.5	3944	33,660	822		32 - 12

Table 10. Colony Development Data, 1930 (Cont. 5)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
56	May 2	5 - 4 oz.	3760	19,740	12,610	63.9	23 - 6 oz.
	" 14				16,580		
	" 22				17,100		
	June 11	11 - 14	4170	49,517	16,880	42.9	70 - 5
	" 23	12 - 15.5	3740	48,503	19,050	39.3	84 - 8
	July 5	12 - 5.5	3828	47,250	16,800	35.6	45 - 10
	" 17	14 - 3	3352	47,138	16,990	36.0	42 - 2
	" 29	16 - 8	3358	55,407	15,810	28.5	40 - 14
	Aug. 10	16 - 7	3300	54,242	17,160	31.6	47 - 5
	" 22	15 - 7	3573	55,156	9,645		39 - 9
	Sept. 3	13 - 13	3614	49,920	11,860	23.8	39 - 7
	" 15	13 - 15.5	3623	50,609	13,130	25.9	41 - 10
	" 27	10 - 10	3738	39,720	10,690		45 - 0
	Oct. 9	9 - 12	3527	34,389	1,343		34 - 2
58	May 2	4 - 12.5 oz.	3880	18,558	11,430	61.6	20 - 2 oz.
	" 14				16,610		
	" 22				17,260		
	June 11	12 - 2.5	4227	51,384	19,670	38.3	69 - 13
	" 23	13 - 10.5	3760	51,335	15,950	31.1	86 - 10
	July 5	11 - 14.5	3974	47,310	17,380	36.7	46 - 2
	" 17	14 - 6.5	3344	48,174	15,700	32.6	44 - 4
	" 29	15 - 15	3638	57,981	16,740	28.9	40 - 6
	Aug. 10	17 - 8.5	3187	55,879	17,420	31.1	43 - 15
	" 22	16 - 11.5	3556	59,449	8,825		39 - 0
	Sept. 3	14 - 12.5	3709	54,826	12,470	22.7	38 - 4
	" 15	13 - 1.5	4000	52,375	10,600	20.2	41 - 15
	" 27	10 - 13	3443	37,225	8,301		43 - 4
	Oct. 9	8 - 12	4040	35,350	959		35 - 10

Table 10. Colony Development Data, 1930 (Cont. 6)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
43	May 13	4 - 9 oz.					12 - 12 oz.
5#	June 24	4 - 4.5	4086	17,492	12,090	67.5	6 - 14
Package	July 6	5 - 4.5	4186	22,109	12,280	55.5	4 - 13
	" 18	7 - 5	3838	28,066	10,500	37.4	17 - 2
	" 30	8 - 11.5	3863	33,676	14,580	43.3	13 - 10
	Aug. 11	9 - 2	3925	35,816	14,850	41.5	15 - 15
	" 23	9 - 5	4604	42,876	12,720	29.7	10 - 11
	Sept. 4	10 - 9.5	3890	41,208	12,250	29.7	11 - 6
	" 15	10 - 3.5	4071	41,599	10,720	25.8	13 - 2
	" 27	8 - 0	3780	30,040	6,055		21 - 3
	Oct. 9	5 - 13	4014	23,333	1,070		22 - 0
46	May 13	2 - 0 oz.					15 - 13 oz.
2#	June 24	2 - 9	4075	10,445	11,240	107.5	8 - 15
Package	July 6	4 - 3.5	4256	17,959	13,100	72.9	6 - 0
	" 18	6 - 7.5	4098	26,508	13,020	49.1	16 - 10
	" 30	8 - 0.5	4345	34,896	13,620	39.0	15 - 6
	Aug. 11	9 - 9	3940	37,674	14,030	37.2	20 - 1
	" 23	10 - 13.5	4024	43,628	12,250	28.1	15 - 14
	Sept. 4	10 - 14	4040	43,760	12,030	27.5	18 - 7
	" 15	10 - 3	3845	39,170	9,319	23.8	20 - 1
	" 27	9 - 6	3160	29,640	3,946		26 - 15
	Oct. 9	7 - 4	3640	26,390			26 - 15

Table 10. Colony Development Data, 1930 (Cont. 7)

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Cells of Sealed Brood	% Ratio of Sealed Brood to Total Bees	Pounds Honey
48	May 13	1 - 11 oz.					14 - 0 oz.
2#	June 24	2 - 12	4180	11,495	13,130	114.3	5 - 10
Package	July 6	5 - 2	3997	20,485	12,820	62.6	4 - 7
	" 18	6 - 9	4513	29,616	14,580	49.2	12 - 8
	" 30	8 - 12	4373	38,263	15,020	39.2	14 - 1
	Aug. 11	9 - 9	4086	39,069	14,740	37.7	21 - 6
	" 23	11 - 1.5	4238	47,016	13,670	29.1	18 - 14
	Sept. 4	12 - 15	4082	52,809	11,860	22.5	19 - 14
	" 15	11 - 4.5	3817	43,062	9,070	21.1	26 - 6
	" 27	9 - 9	4067	38,889	5,754		32 - 8
	Oct. 9	7 - 9	3449	26,087	411		32 - 4
49	May 13	3 - 0 oz.					16 - 13 oz.
3#	June 24	2 - 13	4220	11,872	11,760	99.0	5 - 10
Package	July 6	4 - 12.5	4622	22,088	12,670	57.4	4 - 8
	" 18	6 - 7.5	4062	26,277	13,590	51.9	23 - 9
	" 30	8 - 10	4093	35,304	15,705	44.5	24 - 2
	Aug. 11	9 - 10.5	4440	42,869	14,795	34.6	28 - 13
	" 23	11 - 8	3704	42,596	15,180	35.7	24 - 0
	Sept. 4	11 - 14.5	4104	48,870	14,470	29.6	22 - 12
	" 15	10 - 14.5	3962	43,216	10,800	25.0	29 - 0
	" 27	6 - 1.5	3605	22,967	3,480		36 - 13
	Oct. 9	5 - 3.5	3559	18,572	959		37 - 3

Table 11. Separation of Field Bees from Young Bees*

Colony	Date	Lbs. Bees	Bees Per Lb.	Total Bees	Per Cent of Field Bees	Notes of Manipulation
37	Sept. 8, 1927	15 - 2 oz.	3972	60,080 Y.B.		Colony set back Sept. 6,
	" 8, 1927	1 - 14	5300	9,941 F.B.	14.2	6 p.m.; Sept. 7, a good
				70,021 Total		day for flight.
39	Sept. 8, 1927	9 - 12	3768	36,738 Y.B.		Same
	" 8, 1927	3 - 0	5686	17,058 F.B.	31.7	
				53,796 Total		
41	Sept. 8, 1927	6 - 6	3710	23,652 Y.B.		Same
	" 8, 1927	3 - 14	4820	18,670 F.B.	44.1	
				42,322 Total		
42	Sept. 8, 1927	6 - 10	3680	24,380 Y.B.		Same
	" 8, 1927	2 - 4	5350	12,040 F.B.	33.0	
				36,420 Total		
55 - 56	Oct. 1, 1928	7 - 3	3706	26,938 Y.B.		Colonies set back Sept. 29,
55	" 1, 1928	4 - 0	3969	15,876 F.B.		and united Sept. 30.
56	" 1, 1928	3 - 3	4202	13,395 F.B.		
				56,209 Total	52.8	
57 - 58	Oct. 1, 1928	6 - 6	3816	24,328 Y.B.		Same
57	Oct. 1 , 1928	2 - 2	4998	10,624 F.B.		
58	Oct. 1, 1928	3 - 9	4463	15,909 F.B.		
				50,961 Total	52.3	
21	Aug. 1, 1929	3 - 4	3808	12,376 Y.B.		Colony set back July 29.
Caucasian	Aug. 1, 1929	6 - 7	3920	25,235 F.B.	67.1	
				37,611 Total		
22	Aug. 1, 1929	4 - 14	3611	17,608 Y.B.	(See Col. 23, Table 9)	Same
	" 1, 1929	3 - 9	4138	14,745 F.B.	45.6	
				32,353 Total		

* New hives placed on old stands contained honey and unsealed brood in at least one frame.

Table 12. The Drifting Factor shown in Colonies Undisturbed during the Eight Weeks Prior to the Recording of Flight Data.

1928 Colony	September 18 2 Min. Interval	September 21 2 Min. Interval	September 22 2 Min. Interval
11	Out:109/1 = 1 % Black In :150/0 = 0 % "		Out:161/5 = 3.1 % Black In :196/5 = 2.6 % "
12	Out:141/49 = 35 % Black In :201/62 = 31 % "		Out:142/31 = 21.8 % Black In :153/35 = 22.9 % "
13	Out: 98/1 = 1 % Black In :150/2 = 1.4 % "		Out:144/1 = .7 % Black In :169/4 = 2.4 % "
14 Caucasian	Out:170/61 = 35.9 % Yellow In :149/62 = 41.6 % "		Out:184/62 = 33.5 % Yellow In :259/98 = 37.8 % "
19 Carniolan	Out: 75/18 = 24 % Yellow In : 65/11 = 13.4 % "		Out:106/23 = 22.9 % Yellow In : 92/26 = 28.3 % "
20	Out: 75/15 = 20 % Black In : 61/10 = 16.4 % "		Out:121/10 = 8.26 % Black In :166/10 = 6.2 % "
21 Caucasian	Out: 99/11 = 10.1 % Yellow In :127/17 = 13.4 % "		Out:166/14 = 8.43 % Yellow In :203/28 = 13.8 % "
22	Out: 86/19 = 22.1 % Black In :109/16 = 14.7 % "		Out:161/9 = 5.6 % Black In :163/21 = 12.9 % "

Note: Colony 19, hybrid bees had already begun to emerge from supersedure queen, hence all yellow bees may not have drifted in.

Table 12. The Drifting Factor shown in Colonies Undisturbed during the Eight Weeks Prior to the Recording of Flight Data (Cont. 2)

1928 Colony	September 18 2 Min. Interval	September 21 2 Min. Interval	September 22 2 Min. Interval
23	Out: 47/8 = 17 % Black In : 74/11 = 14.9 % "	Out:132/7 = 5.3 % Black In : 94/7 = 7.45% "	Out: 94/5 = 5.32% Black In :135/5 = 3.7 % "
24	Out: 32/12 = 29.8 % Black In :152/40 = 26.3 % "	Out:105/28 = 26.7 % Black In :243/51 = 21 % "	Out: 85/36 =29.9 % Black In :161/31 =19.3 % "
40 Caucasian	Out:116/3 = 2.59% Yellow In :107/4 = 3.74% "	Out:179/1 = .56% Yellow In :309/1 = .3 % "	
41	Out:111/6 = 5.4 % Black In :103/2 = 1.94% "	Out:166/0 = 0 % Black In :184/1 = .55% "	
42	Out: 78/0 = 0 Black In :113/0 = 0 "	Out:160/0 = 0 Black In :238/0 = 0 "	
29		Out:140/7 = 5 % Black In :205/12 = 5.85% "	
30		Out:167/14 = 8.38% Black In :164/15 = 9.15% "	

Table 14. Wintering Data for Three Seasons - 2-Story Double Walled or Buckeye Hives

Colony	Dates	Fall Bees	Fall Potential Bees	Loss in Stores	Loss or Gain in Bees Number	Loss or Gain in Bees Per Cent	Loss or Gain in Potential Bees Number	Loss or Gain in Potential Bees Per Cent
1927-1928								
20	9/24 to 5/5	44,660	51,030	33 - 2 oz.	-14,639	32.8	-16,844	26.2
19	9/24 " 5/5	40,500	51,180	32 - 2	-23,495	58.0	-29,955	58.6
29	10/8 " 5/5	28,660	28,660	63 - 1	6,535	22.8*	12,180	42.5*
30	10/8 " 5/5	24,616	25,027	54 - 14	- 168	.7	2,874	11.5*
31	10/8 " 5/6	23,925	23,925	53 - 4	1,807	7.6*	5,177	21.6*
32	10/8 " 5/6	18,075	18,842	35 - 7	- 6,899	38.2	- 5,583	29.6
Average		30,073	33,111	45 - 5 oz.	- 6,143	24.0	- 5,355	16.2
1928-1929								
30	10/5 to 5/6	32,409	34,793	30 - 1 oz.	-13,310	41.1	-10,049	28.9
14 Cau.	10/2 " 5/5	25,693	30,023	27 - 9	- 5,697	22.2	1,623	5.4*
29	10/5 " 5/5	27,496	29,414	37 - 13	- 2,729	9.9	10,753	36.6*
1	10/6 " 5/6	27,659	27,960	32 - 12	- 2,134	7.7	10,715	38.3*
4	10/2 " 5/5	16,718	18,773	29 - 15	-11,294	67.5	(Queenless)	
13	10/2 " 5/6	16,494	18,440	26 - 11	- 4,218	25.6	3,756	20.4*
Average (Col. 4 Omitted)		25,950	28,126	30 - 13 oz.	- 5,618	21.6	3,367	12.0*
1929-1930								
13	10/5 to 5/2	35,008	35,008	34 - 11 oz.	-19,257	55.0	- 7,447	21.3
29	10/5 " 5/2	30,797	31,290	27 - 7	-20,817	67.6	-13,010	41.6
1	10/4 " 5/1	29,075	29,075	31 - 7	- 9,851	33.9	99	0.0
19 Cau.	10/4 " 5/1	25,062	25,062	32 - 12	-10,710	42.7	- 2,570	10.3
Average		29,985	30,109	31 - 9 oz.	-15,159	50.6	- 5,731	15.3

Table 15. Wintering Data for Two Seasons - 2-Story Single Walled Hives - Newspaper-Tarpaper Pack

Colony	Dates	Fall Bees	Fall Potential Bees	Loss in Stores	Loss or Gain in Bees Number	Loss or Gain in Bees Per Cent	Loss or Gain in Potential Bees Number	Loss or Gain in Potential Bees Per Cent
1928-1929								
31	10/5 to 5/5	22,362	24,692	36 - 7 oz.	- 288	1.3	7,632	30.9*
3	10/6 " 5/6	21,369	23,014	31 - 0	- 2,458	11.5	5,847	25.4*
Average		21,865	23,853	33 - 12 oz.	- 1,373	6.3	6,739	28.3*
1929-1930								
55	10/6 to 5/2	37,536	37,536	36 - 6 oz.	-14,261	38.0	289	.8*
14	10/5 " 5/2	36,475	36,475	44 - 14	- 9,656	26.5	2,564	7.0*
23	10/4 " 5/1	31,630	33,685	44 - 5	- 3,405	10.8	8,950	26.6*
Average		35,214	35,899	41 - 14 oz.	- 9,107	25.9	3,934	11.0*

Table 16. Wintering Data for One Season - 2-Story Single Walled Hives - No Insulation

Colony	Dates	Fall Bees	Fall Potential Bees	Loss in Stores	Loss or Gain in Bees Number	Loss or Gain in Bees Per Cent	Loss or Gain in Potential Bees Number	Loss or Gain in Potential Bees Per Cent
1929-1930								
2	10/5 to 5/1	35,388	35,771	49 - 4 oz.	- 6,574	18.6	6,883	19.2*
6	9/28 " 5/1	34,975	34,975	44 - 1	-15,654	44.7	- 5,702	16.3
56	10/6 " 5/2	33,865	33,865	36 - 7	-14,125	41.7	- 1,515	4.5
Average		34,743	34,870	43 - 4 oz.	-12,118	34.9	- 111	0.0

Table 17. Wintering Data for Two Seasons - 2-Story Single Walled Hives - Top and Bottom Pack

Colony	Dates	Fall Bees	Fall Potential Bees	Loss in Stores	Loss or Gain in Bees Number	Loss or Gain in Bees Per Cent	Loss or Gain in Potential Bees Number	Loss or Gain in Potential Bees Per Cent
1928-1929								
11	10/6 to 5/6	26,585	28,585	46 - 5 oz.	- 6,571	24.7	3,599	12.6*
1929-1930								
20	10/5 to 5/1	44,688	46,295	44 - 11 oz.	-18,432	41.3	- 7,269	15.7
3	9/28 " 5/2	43,250	43,250	40 - 7	- 7,184	16.6	7,162	16.6*
Average		43,969	44,772	42 - 9 oz.	-12,808	29.1	- 53	0.0

Table 18. Wintering Data for Three Seasons - 2-Story Langstroth Hives - Leaf Pack

Colony	Dates	Fall Bees	Fall Potential Bees	Loss in Stores	Loss or Gain in Bees Number	Loss or Gain in Bees Per Cent	Loss or Gain in Potential Bees Number	Loss or Gain in Potential Bees Per Cent
1927-1928								
24	10/5 to 5/2	40,096	41,192	54 - 10 oz.	-14,704	36.7	-12,800	31.1
49	10/8 " 5/5	17,600	18,696	49 - 7	1,481	8.4*	4,195	22.4*
50	10/8 " 5/5	13,404	15,597	13 - 8	- 4,804	35.8	- 6,504	41.7
Average		23,700	25,162	39 - 3 oz.	- 6,009	25.4	- 5,036	20.0
1928-1929								
58	10/1 to 5/6	32,333	32,333	13 - 14 oz.	-21,309	67.0	-12,707	39.3
2	10/1 " 5/5	21,650	27,460	28 - 1	- 1,194	5.5	- 399	1.4
20	10/6 " 5/6	22,536	24,454	33 - 1	1,065	4.7*	11,397	46.6*
Average (Col. 58 Omitted)		22,093	25,957	30 - 9 oz.	- 64	0.0	5,500	21.0*

Table 18. Wintering Data for Three Seasons - 2-Story Langstroth Hives - Leaf Pack (Cont. 2)

Colony	Dates	Fall Bees	Fall Potential Bees	Loss in Stores	Loss or Gain in Bees Number	Loss or Gain in Bees Per Cent	Loss or Gain in Potential Bees Number	Loss or Gain in Potential Bees Per Cent
1929-1930								
4	10/5 to 5/2	38,953	38,953	40 - 11 oz.	- 5,053	13.0	10,677	27.4*
30	10/4 " 5/1	35,134	35,709	34 - 8	- 8,078	23.0	3,977	11.1*
58	10/6 " 5/2	37,788	37,788	38 - 11	-19,330	50.9	- 7,800	20.6
Average		37,292	37,483	37 - 15 oz.	-10,787	28.9	2,285	6.1

Note: Colony 24, 1927-1928, obtained by uniting two colonies.
Colony 58, 1928-1929, consisted of old bees from two colonies, separated and united Sept. 29,1930.

Table 19. Wintering Data for Two Seasons - 2-Story Single Walled Hives - Single Colony Case

Colony	Dates	Fall Bees	Fall Potential Bees	Loss in Stores	Loss or Gain in Bees Number	Loss or Gain in Bees Per Cent	Loss or Gain in Potential Bees Number	Loss or Gain in Potential Bees Per Cent
1927-1928								
	9/24	36,130	39,528	United				
	10/10	16,090	16,090					
57	5/2	52,220	55,618	46 - 10 oz.	-22,446	43.0	-18,501	33.3
56	5/2	45,826	50,447	36 - 8	-26,653	58.1	-26,451	52.4
	10/1	27,810	29,620	United				
	10/8	18,015	20,827					
Average		49,023	53,033	41 - 9 oz.	-24,550	49.9	-22,476	41.5
1928-1929								
56	10/1 to 5/5	26,938	38,778	22 - 7 oz.	- 7,724	28.7	-11,094	28.6
57	10/1 " 5/5	24,327	30,411	34 - 13	- 3,469	14.3	202	.7*
Average		25,633	34,594	28 - 10 oz.	- 5,596	21.8	5,446	15.8

Note: Each contained young bees from two colonies; separated from old bees Sept. 29, united Oct. 1.

Table 20. Wintering Data for Two Seasons - 2-Story Single Walled Hive - Two Colony Case

Colony	Dates	Fall Bees	Fall Potential Bees	Loss in Stores	Loss or Gain in Bees Number	Loss or Gain in Bees Per Cent	Loss or Gain in Potential Bees Number	Loss or Gain in Potential Bees Per Cent
1927-1928								
2	9/26 to 5/3	36,924	41,010	42 - 9 oz.	-10,958	29.7	-10,355	25.3
1	9/26 " 5/3	35,148	40,328	30 - 1	-13,898	39.5	-15,424	38.2
Average		36,037	40,669	36 - 5 oz.	-12,428	34.5	-12,889	31.7
1928-1929								
21 Cau.	10/2 to 5/5	23,915	27,697	28 - 5 oz.	-15,844	66.2	-14,090	50.9
22	10/2 " 5/6	22,930	24,848	21 - 14	-13,461	58.7	- 8,281	33.3
Average		23,422	26,273	25 - 3 oz.	-14,652	62.6	-11,185	42.6

Table 21. Wintering Data for Three Seasons - 2-Story Single Walled Hives - Quadruple Case

Colony	Dates	Fall Bees	Fall Potential Bees	Loss in Stores	Loss or Gain in Bees Number	Loss or Gain in Bees Per Cent	Loss or Gain in Potential Bees Number	Loss or Gain in Potential Bees Per Cent
1927-1928								
35	10/2 to 5/9	36,878	36,987	40 - 11 oz.	- 3,972	10.8	4,743	12.8*
33	10/2 " 5/9	26,515	30,780	37 - 14	-11,411	42.9	- 9,565	31.1
36	10/2 " 5/9	26,730	28,922	29 - 1	-10,560	39.5	- 4,341	15.0
34	10/2 " 5/9	25,020	26,118	28 - 2	-11,279	45.1	- 6,594	25.6
Average		28,786	30,702	33 - 15 oz.	- 9,306	32.3	- 3,940	12.8
1928-1929								
34	10/7 to 5/7	26,035	26,090	26 - 3 oz.	-15,477	59.4	- 6,407	24.6
35	10/7 " 5/7	23,726	24,906	25 - 8	176	.7	10,236	41.1*
36	10/7 " 5/7	17,766	19,366	31 - 14	- 5,424	30.5	3,376	17.4*
33	10/7 " 5/7	11,478	13,561	22 - 7	- 5,661	49.3	- 3,934	29.0
Average		19,751	20,981	26 - 8 oz.	- 6,596	33.4	818	3.8*

Table 21. Wintering Data for Three Seasons - 2-Story Single Walled Hives - Quadruple Case (Cont. 2)

Colony	Dates	Fall Bees	Fall Potential Bees	Loss in Stores	Loss or Gain in Bees Number	Loss or Gain in Bees Per Cent	Loss or Gain in Potential Bees Number	Loss or Gain in Potential Bees Per Cent
1929-1930								
8	10/4 to 5/1	43,332	45,113	41 - 2 oz.	-19,203	44.3	- 9,999	22.2
36	10/5 " 5/2	42,588	42,588	33 - 15	-35,976	84.5	-33,783	79.3
34	10/4 " 5/1	41,562	41,562	37 - 6	-27,413	66.0	-19,112	46.0
33	10/5 " 5/1	37,140	37,140	38 - 3	-22,396	60.3	-14,690	39.6
10	10/5 " 5/2	35,479	35,890	38 - 9	- 9,611	27.1	- 2,102	5.9
7 Cau.	10/5 " 5/2	33,143	36,185	(Drone Layer)				
35 Cau.	10/4 " 5/1	33,540	33,540	27 - 10	-24,983	74.5	-21,639	64.5
9	10/4 " 5/1	30,993	30,993	35 - 5	-10,373	33.5	1,407	4.5*
Average		37,805	39,007	36 - 3 oz.	-21,422	56.7	-14,274	36.6

Table 22. Wintering Data for Two Seasons - Modified Dadant Hives - Three Colony Case

Colony	Dates	Fall Bees	Fall Potential Bees	Loss in Stores	Loss or Gain in Bees Number	Loss or Gain in Bees Per Cent	Loss or Gain in Potential Bees Number	Loss or Gain in Potential Bees Per Cent
1927-1928								
37	9/25 to 5/8	40,012	44,643	30 - 6 oz.	-19,998	50.0	-17,943	40.2
39	9/25 " 5/8	25,320	29,129	27 - 9	-14,925	59.0	-15,254	52.4
38	9/25 " 5/10	18,582	21,158	23 - 13	-15,174	81.6	-16,818	79.5
42	10/1 " 5/10	16,415	20,389	29 - 15	- 1,654	10.1	- 38	0.0
40	10/1	16,809	17,384	(All but queen and "200" bees)				
41	10/1 to 5/8	16,850	16,850	25 - 11	-12,530	74.3	-10,968	65.1
Average		22,331	24,926	27 - 7 oz.	-13,515	60.5	-13,068	52.4
1928-1929								
40 Cau.	10/7 to 5/6	21,963	24,046	9 - 1 oz.	-13,871	63.2	- 9,817	40.8
42	10/7 " 5/6	21,937	22,787	(All but queen and "200" bees)				
41	10/7 " 5/6	16,100	16,703	24 - 11	-10,353	64.3	- 5,804	34.8
Average		20,000	21,178	16 - 14 oz.	-15,390	77.0	-12,736	60.2

Note: Colonies 40 (1927-1928) and 42 (1928-1929) included in averages except in loss of stores.

Table 23. Wintering Data for Three Seasons - 1-Story Single Walled Hives - Cellar Wintering

Colony	Dates	Fall Bees	Fall Potential Bees	Loss in Stores	Loss or Gain in Bees Number	Loss or Gain in Bees Per Cent	Loss or Gain in Potential Bees Number	Loss or Gain in Potential Bees Per Cent
1927-1928								
54	10/4-8 to 5/6	30,346	30,647	22 - 10 oz.	- 7,607	25.1	- 2,777	9.1
52	9/24 " 5/6	24,993	32,666	21 - 15	-18,094	72.4	-24,424	74.8
53	9/24 " 5/6	20,085	22,633	26 - 12	- 4,293	21.9	- 4,018	17.7
43	10/10 " 5/5	20,467	20,467	28 - 6	- 4,386	21.4	- 494	2.4
44	10/1 " 5/5	18,789	21,499	29 - 13	-10,047	53.5	-10,457	48.7
46	10/4 " 5/3	16,780	18,150	23 - 15	- 8,055	48.0	- 7,425	25.8
45	10/4 " 5/5	10,120	10,723	30 - 15	- 5,480	54.2	- 5,043	47.0
Average		20,225	22,398	26 - 5 oz.	- 8,280	40.9	- 7,805	34.8
1928-1929								
12	10/1 to 5/5	19,618	24,304	20 - 7 oz.	- 4,584	23.4	- 558	2.3
23	10/6 " 5/6	16,433	17,858	20 - 4	- 7,358	44.8	- 1,109	6.2
Average		18,025	21,081	20 - 6 oz.	- 5,971	33.1	- 833	3.9
1929-1930								
12	10/5 to 5/1	30,086	30,086	24 - 13 oz.	-14,196	47.2	- 5,665	18.8

Note: Colony 54 (1927-1928) was obtained by uniting two colonies; one evaluated October 4, one October 8.

Table 24. Combined Summary of Wintering Methods for the Seasons of 1927-1928, 1928-1929, and 1929-1930

Winter Protection	Total No. Colonies	Number Seasons	Bees in Fall	Potential Bees in Fall	Loss in Stores	Loss in Bees Number	Loss in Bees PerCent	Loss or Gain in Potential Bees Number	Loss or Gain in Potential Bees PerCent	
Newspaper	5	2	28,539	29,879	37 - 13	- 5,240	18.4	5,336	17.9 *	
Top and Bottom	3	2	35,277	36,678	44 - 7	- 9,689	27.5	1,773	4.8 *	
Leaf	8	3	27,695	29,534	35 - 14	- 5,620	20.3	916	3.1 *	
None	3	1	34,743	34,870	43 - 4	-12,118	34.9	- 111	.3	
Buckeye	15	3	28,669	30,449	35 - 14	- 8,973	31.2	- 2,573	8.5	
Single Case	2	1	25,633	34,594	28 - 10	- 5,596	21.8	- 5,446	15.7	(All young bees)
Cellar	10	3	22,779	26,782	23 - 13	- 9,482	41.6	- 4,768	17.8	
Quadruple	15	3	28,781	30,230	37 - 14	-12,441	43.2	- 5,799	19.2	
Two Colony Case	4	2	29,729	33,471	30 - 12	-13,540	45.5	-12,037	36.0	
Leaf	1	1	32,333	32,333	13 - 14	-21,309	67.0	-12,707	39.3	(All old bees)
Single Case	2	1	49,023	53,033	41 - 9	-24,550	50.1	-22,476	42.4	(United Col.)
Three Colony Case	9	2	21,166	23,052	22 - 3	-14,452	54.2	-12,902	56.0	

* Per Cent Gain in Potential Bees.

PLATES

Explanation of Plate 1

Method of Plotting:

Honey flow data obtained from changes in weight of a full strength colony on scales.

Net loss or gain of scale colony for the 12-day egg-laying periods of colonies 19 and 20, 1927; 1 and 2, 1928; 55 and 56, 1929.

Positive numbers to right of honey flow bars indicate the number of days the scale colony gained in weight; negative numbers, the days showing a loss.

Periods following a broken line show an estimated brood level due to a change in queen.

Description of Colonies:

1927. Colonies 19 and 20 were overwintered. Queen 19 was replaced May 29 with queen from package installed April 29. Queen 20 was replaced June 22 with Italian queen reared locally. Colonies 30 and 31 were packages installed April 29, having 3 lbs.-11 oz. and 3 lbs.-8 oz. of bees, respectively.

1928. All four colonies were wintered with Italian queens reared in 1927. Extreme dearth of pollen from April 15 to May 1; brood-rearing had been at a relatively high level during late March and early April although no actual measurements were made.

1929. All full strength overwintered colonies which had participated in continuous honey flow from May 15 to July 15 during which time the scale colony gained 180 pounds. Colonies 19 and 35 were requeened with Caucasian queens July 27; 55 and 56 with Italian queens July 29.

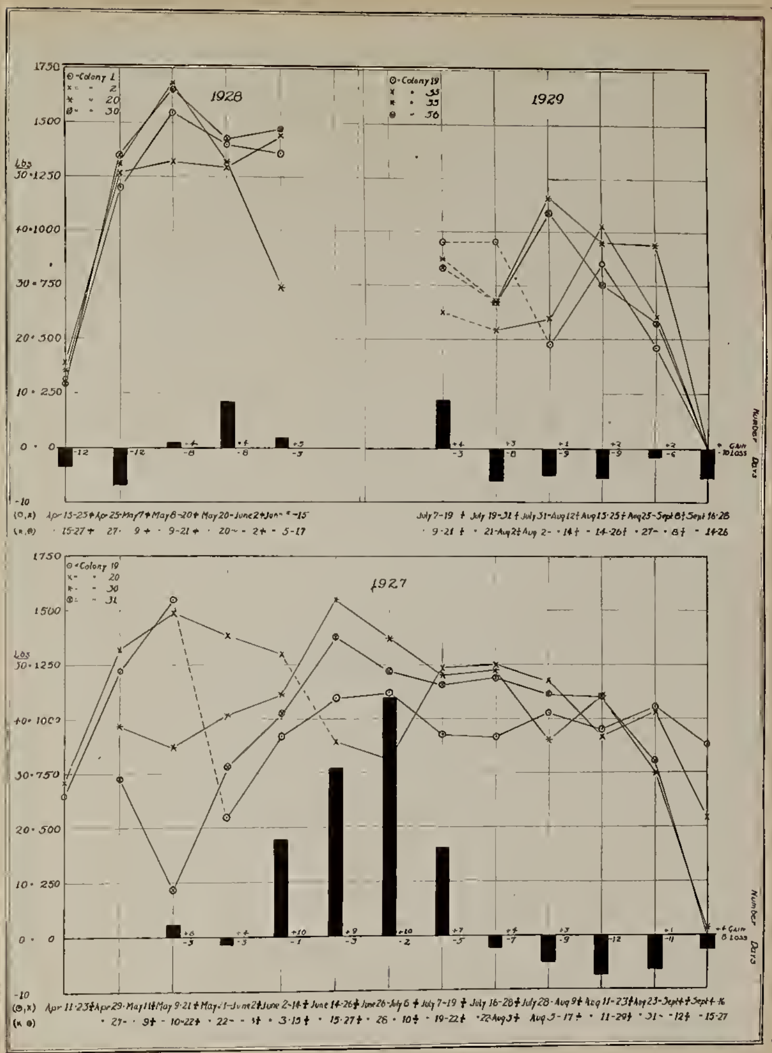

Plate 1

Average Daily Rates of Brood-rearing Based upon Sealed Brood Measurements but Plotted for the Periods of Egg Laying, 1927, 1928, and 1929.

Explanation of Plate 2

Method of Plotting:

See explanation of Plate 1.

Description of Colonies:

Colonies 19 and 35 were wintered with Caucasian queens introduced July 1929. Colonies 56 and 58 were wintered with Italian queens, also introduced July 1929. Caucasian queen 35 was unsuccessfully superseded during early July; young Italian queen introduced July 17. Queens 56 and 58 were replaced with young Italian queens August 10.

Colonies 48, 49 and 43, 46 were established from packages May 13. The unbroken brood curve shows the mean rate for colonies 48 and 49; the broken brood curve shows the mean for colonies 43 and 46. The unbroken and broken "Stimulative Feeding" curves correspond with the brood curves, respectively. Sugar in $\frac{1}{2}$-pound units diluted to make one pint of syrup was fed each evening with Boardman entrance feeders.

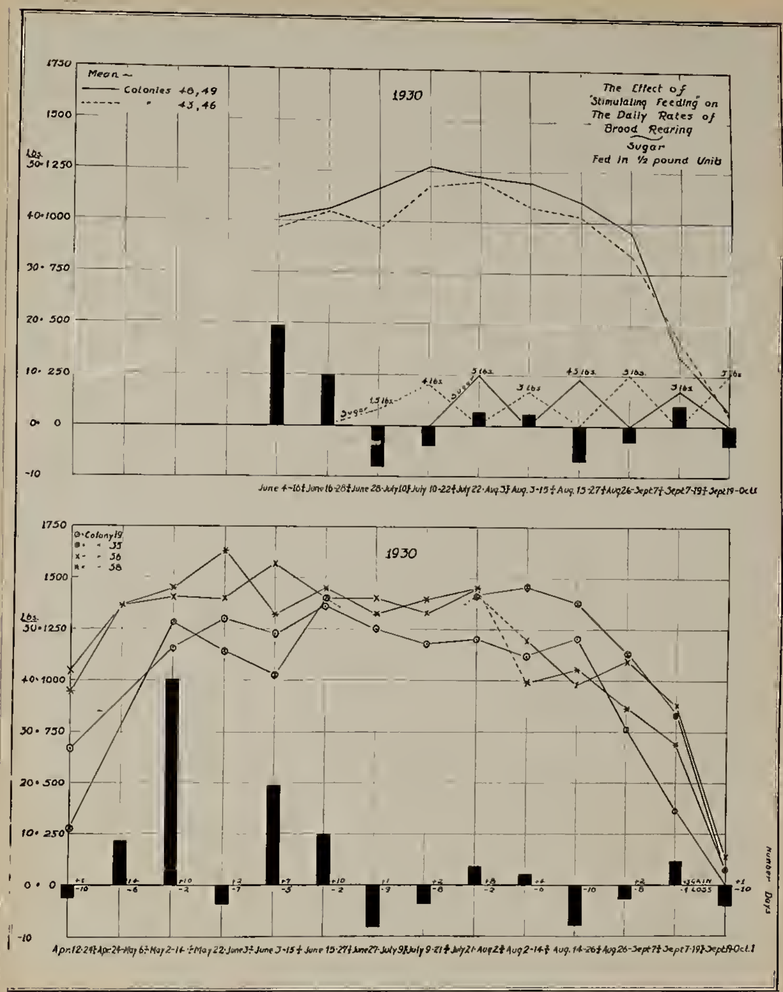

Plate 2

Average daily rates of brood-rearing based upon sealed brood measurements but plotted for the period of egg laying, 1930.

Explanation of Plate 3

Figures 1 and 2. The percentage ratios of sealed brood to total bees were obtained by dividing the number of cells of sealed brood by the number of bees found in the hive at identical periods.

Figures 3 and 4. The average daily rates of brood-rearing were obtained by dividing the number of cells of brood by 12.

The season of 1930 exhibited very few seasonal changes on brood-rearing (See Plates 2, 9, and 10).

In each figure, unlabeled curves indicate tendencies shown by the included data. The upper curves labeled "Optimum" have been interpreted as showing the optimum relation between the variable factors for colonies varying in strength from 20,000 to 50,000 bees.

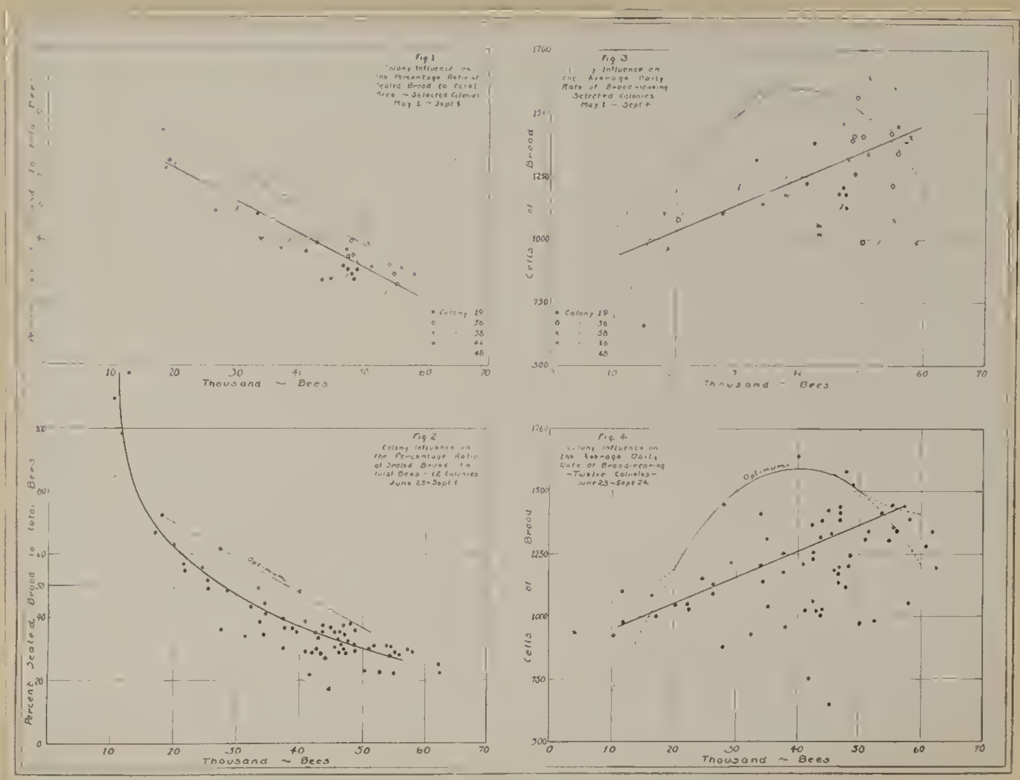

Plate 3

Colony influence on brood-rearing, 1930.

Explanation of Plate 4

Similar to figures 1 and 2, Plate 3.

The straight line curves labeled "Optimum" were interpreted from data shown in figure 2, Plate 3, and drawn here to show how similar data for other seasons or sections of seasons are distributed in respect to the interpreted optimum curve.

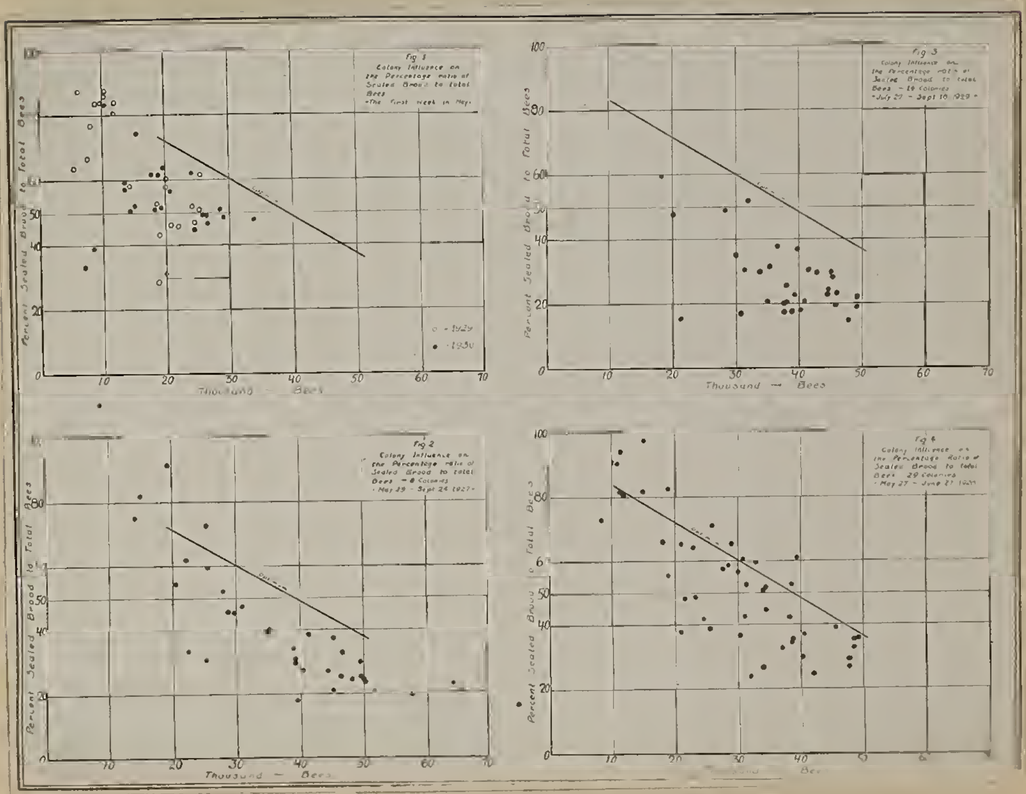

Plate 4

Colony influence on brood-rearing 1927, 1928, 1929, and 1930.

Explanation of Plate 5

Method of Plotting:

Each full column indicates the number of bees in thousands which could have been in the colony on that day. In the few cases where the brood observations were not made at exactly 12-day intervals, compensations were made for the intervening days. The narrow unshaded portion indicates the number of bees present; the narrow black portion indicates the bees which had emerged during the previous 12 days; the narrow shaded portion indicates the bees which were more than 12 days old; the cross-hatched portion indicates the bees which had died since the previous determination (in most instances 24 days); the inset numbers indicate the theoretical maximum age of the oldest bees present. The full black column (using the 85 thousand level as the zero line) indicates the loss or gain in pounds of honey since the previous determination (Colonies 19 and 20 produced between 75 and 100 pounds from the period June 22 to July 16 though accurate records were omitted; this gain is represented by a question mark).

Description of Colonies:

Colonies 19, 20, 53, and 54 were overwintered but were below normal strength due to lack of bees and honey in all colonies the previous fall. Colonies 29, 30, 31, 32, and 47 were installed from packages having 3 lbs.-11 oz., 3 lbs.- 8 oz., 2 lbs.- 8 oz., colony 32 indefinite, and 3 lbs. of bees, respectively (29 and 30 were installed April 29, and 31, 32, and 47 April 20).

Colonies 19, 20, 29, and 30 were housed in 2-story double walled (Buckeye) hives during the first, third, fifth, and seventh "24" day periods, being transferred to single walled hives for the intervening periods during which time 53, 54-47, 31, and 32 were housed in the double walled equipment.

The origin of the overwinter queens was unknown; the package queens were all bred from one breeder (Strain A), while queens reared locally were all daughters of this strain. Colony 19 was requeened May 29 with a queen taken from a package. Colonies 20 and 53 were requeened June 22 with daughters from package colony 42. Package queen of colony 32 was superseded the last day of May but was replaced by uniting another small package colony. Colony 19 had one queen cell in lower brood chamber on July 16. Supersedure cells were present June 10 in colony 53. Package colony 29 had supersedure cells July 30 and was requeened with daughter of colony 30.

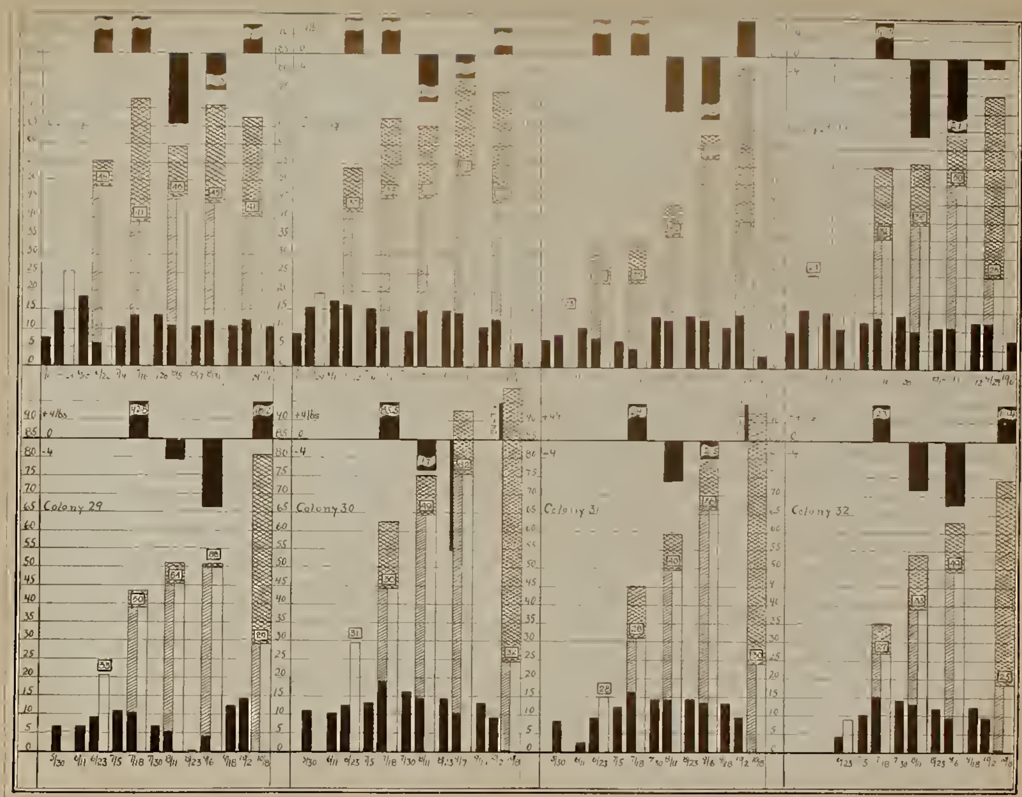

Plate 5

Colony development 1927

Explanation of Plate 6

Methods of Plotting:

See explanation of Plate 5.

Description of Colonies:

Division of Colonies. Colonies 56 and 57 were divided on May 3, and colonies 55 and 58, mostly sealed brood and adhering bees, were obtained, respectively. Colony 55 was given overwintered package queen No. 40 (Strain A) which had survived with approximately only 200 workers; colony 58 was given a purchased queen (Strain C). Data for both colonies in each pair are plotted separately and also as combined colonies. The inserted question marks on May 27, colonies 56 and 57, indicate that a portion of the bees represented as having died had been carried over into the new colonies. The combined data for the same dates show the bees which had actually died.

Removal of Brood. All the brood was removed from colonies 20 and 30 on June 11, indicated by broken "brood" bar in chart.

Addition of Brood. Colony 29 was moved to position 12 on June 11 and the brood from 30 placed in care of the returning bees; Caucasian queen (Strain E) was introduced. Data plotted for colony 29, June 26, shows the new colony 29 superimposed upon the original colony moved to location 12.

Description of Queen. Colonies 19 and 30 were headed by 1927 package queens (Strain A); daughters of queen 42 (Strain A) were introduced into 20, 24, and 57 in June, and into 44, 45, and 56 in July, 1927; daughter of queen 30 (Strain A) was introduced into colony 29 August 1927. Purchased queens (Strain B) were introduced into colonies 1 and 2, July 1927.

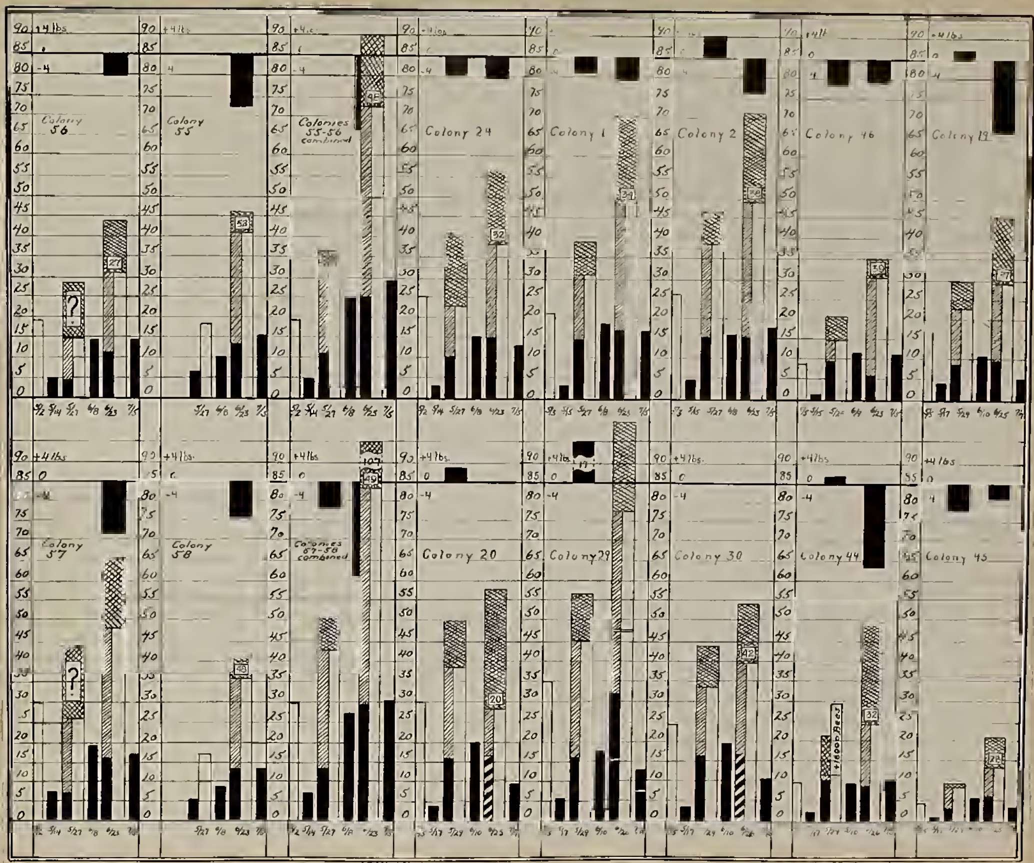

Plate 6

Colony development 1928

Explanation of Plate 7

Methods of Plotting:

See explanation of Plate 5.

Description of Colonies:

Equalized Colonies. Exchanged positions of colonies 37 and 38, May 10. However, data are plotted for the original colonies as numbered. The inserted question mark, colony 37, June 1, indicates that a portion of the bees represented as having died had joined colony 38. The bees thus added to colony 38 just equalled the number of bees which died between May 10 and June 1.

Removal of Bees or Brood. Colony 37 moved to location 40, June 11, and brood of 42 placed in care of the returning bees. The inserted question mark, colony 37, June 27, indicates that a portion of the bees represented as having died were the young bees removed through the above manipulation.

The brood was removed from colony 42, June 11; thus the bees represented for this colony on June 27 were all older than 16 days.

Description of Queens. Colonies 31, 32, 37, 39, 41, and 42 were headed by 1927 package queens (Strain A); 35 by daughter of 30 (Strain A); 36, 53, and 54 by daughters of 42; 49 by a supersedure granddaughter of colony 42; 33, 34, 38, and 52 by 1927 queens obtained by supersedure of Italian queens of unknown origin.

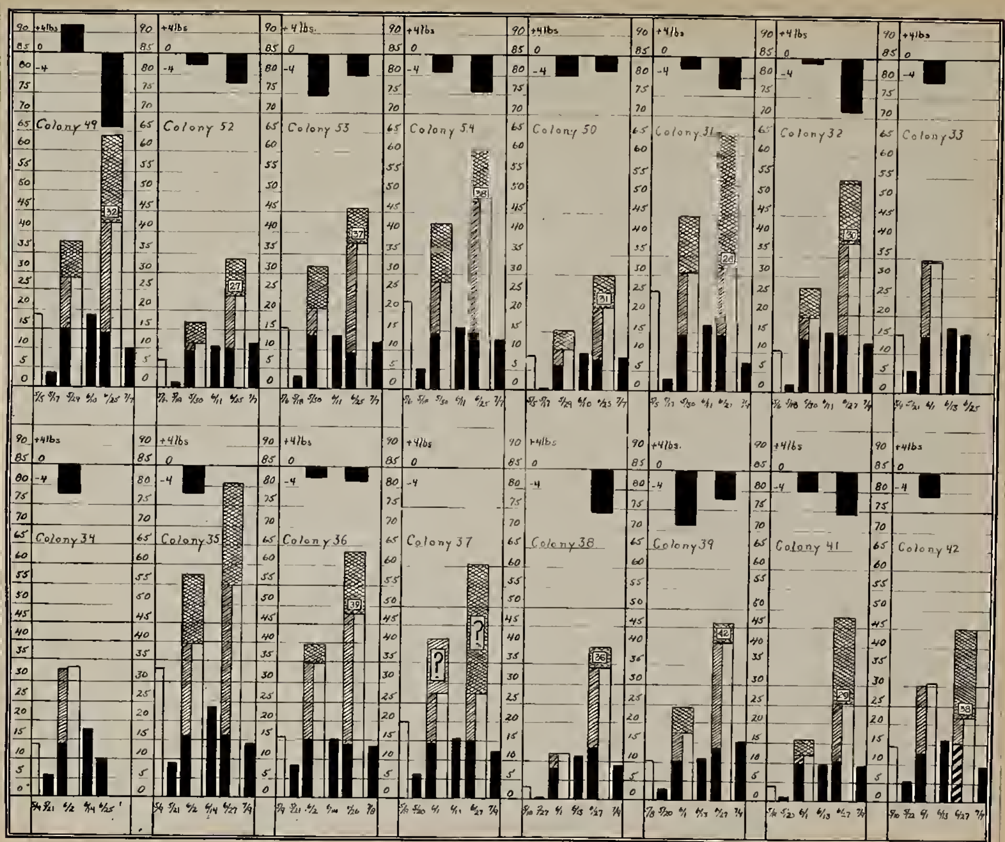

Plate 7

Colony development 1928

Explanation of Plate 8

Method of Plotting:

See explanation of Plate 5.

Description of Colonies:

All colonies normal (except 23) which had participated in a series of exceptionally good honey flows from the middle of May to the middle of July (See seasonal honey flow conditions). Colony 23 was moved from location 22 on July 29 and therefore lost the returning field bees.

Description of Queens:

Queens heading colonies 1, 2, 29, 30, 56, 57, 58, and 59 were replaced with purchased queens (Strain A) when the first records were obtained between July 29 and August 1. Those heading colonies 7, 19, and 35 were replaced with Caucasian queens (Strain E) July 27. Queen 23 was a daughter of queen 31 (Strain A) introduced in June; Queen 60 was a supersedure queen (Strain B) just commencing to lay the last of July.

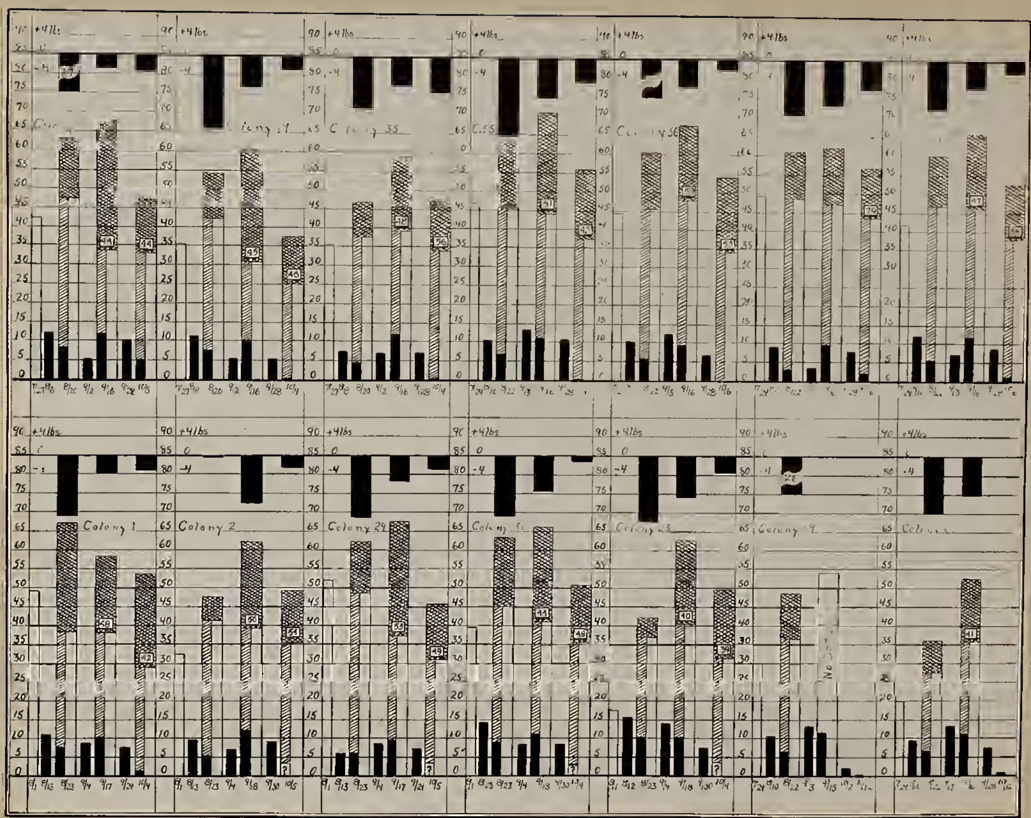

Plate 8

Colony development 1929

Explanation of Plate 9

Method of Plotting:

See explanation of Plate 5. Full colony records were obtained, however, every 12 days. The bees shown as having died were therefore lost during 12-day periods.

Description of Colonies:

Manipulation. All combs in colony 6 were replaced with frames of foundation on May 7, during a heavy flow. Colonies 12 and 20 received full sheets of foundation for storage space, while all the other colonies received drawn combs. Drifted Caucasian bees were noticeably evident in colony 29, Sept. 15.

Seasonal Net Loss or Gain in Honey. Colony 6, 5 lbs.-11 oz. loss; colony 12, 7 lbs. loss; colony 20, 14 lbs.-3 oz. gain; colony 29, 6 lbs.-4 oz. gain; colony 56, 76 lbs.-10 oz. gain; colony 58, 87 lbs-12 oz. gain.

Description of Queens. All young queens introduced were bred from queen 23 (Strain A, see 1929 record). Colony 6, May 1929 supersedure queen (Strain A) requeened July 17; removed numerous unsealed queen cells Aug. 10; replaced this inferior queen Aug. 22. Original queens in colonies 12, 20, 29, 56, and 58 were purchased queens (Strain A) introduced the first of August 1929. Colony 12, removed queen cells June 10; young queen introduced July 5; six queen cells removed and inferior queen replaced July 26. Colony 20, three queen cells removed June 23; requeened July 7. Colony 29, requeened July 5; two frames containing young brood and evidence of virgin queen being present; inferior queen replaced July 29. Colonies 56 and 58 requeened Aug. 10.

Errata: The chart dates 5/1 and 5/13 for colonies 29, 56, and 58 should read 5/2 and 5/14, respectively.

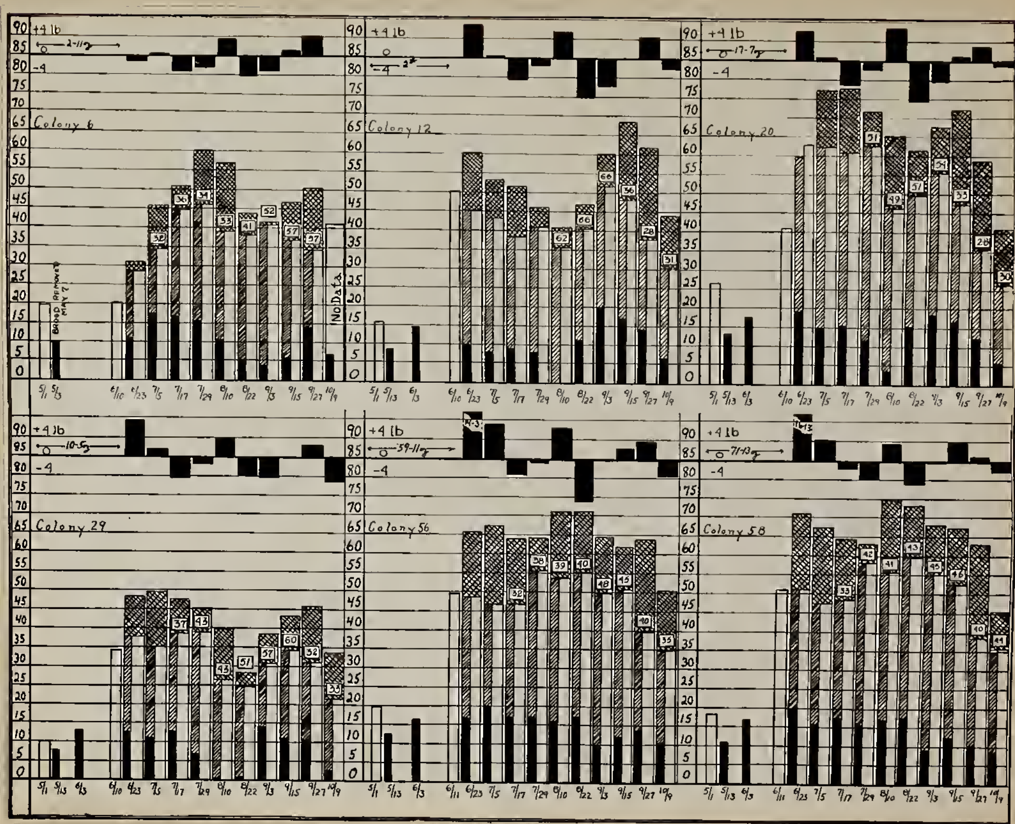

Plate 9

Colony development 1930

Explanation of Plate 10

Method of Plotting:

See explanation of Plate 5 (Intervals similar to Plate 9). Broken line shading, indicating changes in stores (colonies 43, 46, 48, and 49) shows the weight of dry sugar fed. In plotting the loss or gain in honey, one pound of dry sugar was assumed to be equivalent to one pound of honey.

Description of Colonies:

Manipulations. All colonies received drawn combs as needed. Colony 35 (Caucasian) was noticeably influenced by the presence of drifting bees except on the first determination, May 1, showing 21.5% Italian bees on June 23, and 12.8%, 17.6%, 20;4%, 20%, and "18%" for the successive periods up to and including Aug. 22. Colonies 43, 46, 48, and 49 were installed as packages May 13, having 4 lbs.-9 oz., 2 lbs., 1 lb.-11 oz., and 3 lbs. of bees, respectively. The original weights of 46 and 48 have but little significance since practically all the bees of 48 drifted into 46 making 46 appear similar in strength to 43. Colonies 46 and 48 were exchanged in position May 28, each taking the number of its new position.

Seasonal Net Loss or Gain in Honey. Caucasian colonies 19 and 35 gained 26 lbs.-13 oz. and 12 lbs.-2 oz., respectively. Assuming that one pound of dry sugar fed was equivalent to one pound of honey, package colonies 43, 46, 48, and 49 lost 22 lbs.-13 oz., 18 lbs.-15 oz., 7 lbs.-4 oz., and 18 lbs.-12 oz., respectively.

Description of Queens. Queens 43, 46, 48, and 49 were package queens (Strain D); queen 43 was noticeably inferior. Queens 19 and 35 were purchased (Strain E, Caucasian) and introduced July 27, 1929. Queen 35 was lost July 5 and replaced by a daughter of 23 (Italian, Strain A).

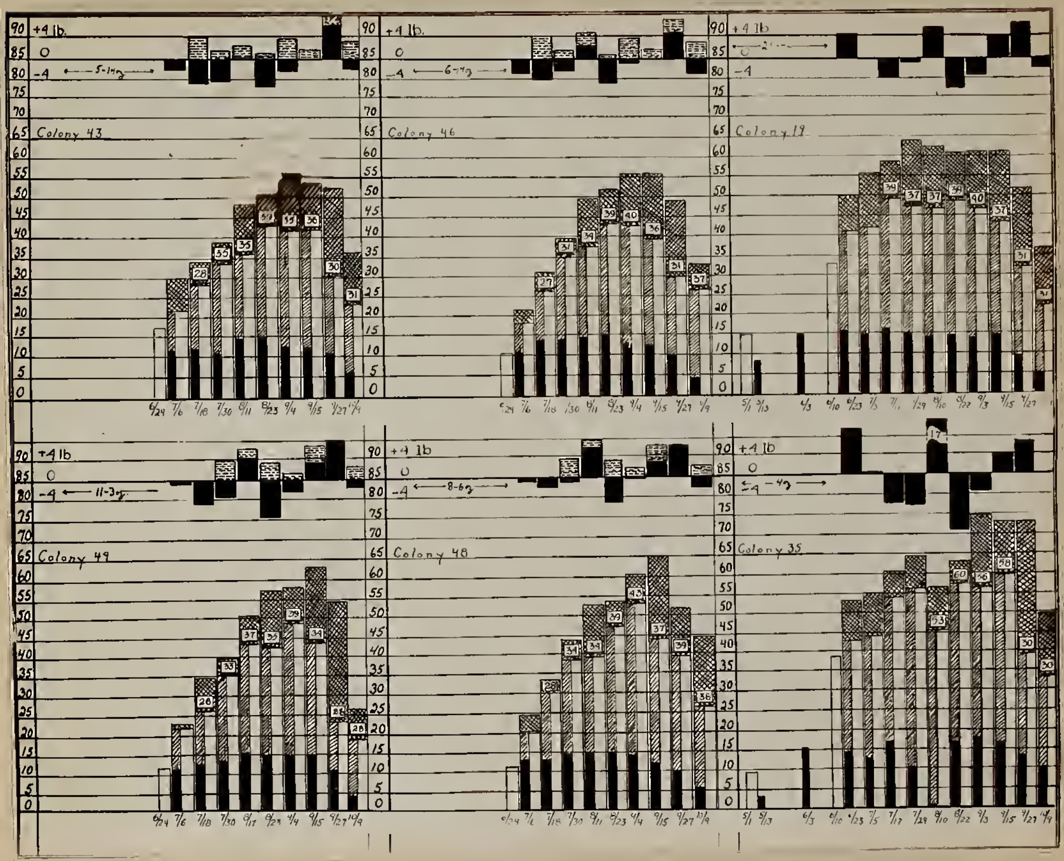

Plate 10

Colony development 1930

Explanation of Plate 11

Method of Plotting:

The decimal points for the temperatures mapped show the relative positions of the thermo-couples which were located midway between the adjacent comb surfaces. Thermo-couples between lower combs were 4" apart in each direction within the vertical plane; between the upper combs they were $2\frac{1}{2}$" horizontally and 1 1/8" vertically; in colony 59, one additional thermo-couple was placed centrally, just beneath the top bar. The interspace diagrammed as separating the upper and lower comb was occupied by the bar of the lower comb, a bee space, and the bottom bar of the upper comb. Row 1 shows the temperatures recorded between right surface of the first comb and the hive wall; Row 2 shows the temperature recorded between first and second combs, etc., there being nine combs spaced $1\frac{1}{2}$" from center to center.

Brood, honey and pollen areas as mapped show only the condition found on the right side of the comb. The brood found on the right side of a comb will usually be duplicated on the left side. Pollen and unsealed honey may fill most cells facing the cluster and be entirely lacking on the opposite side.

Description of Periods:

Series A shows that the entire brood nest was located in the upper set of combs, numbers 2 to 7, inclusive.

Series B shows the brood nest ten days after the upper combs had been exchanged with the corresponding lower combs; brood now present in twelve combs instead of six. The colony had been collecting nectar freely for four days.

Series C. The combs were filled with sealed honey. A full comb of brood (Row 5 upper) was removed the middle of May and frame 1, containing honey, substituted in its place.

Series D shows the brood nest of a young queen which had been laying only 24 to 26 days. The upper combs were newly drawn.

Series E. The queen's preference for old combs is noticeably evident. Note the tendency for lower temperatures on the outer surface of the outside brood combs.

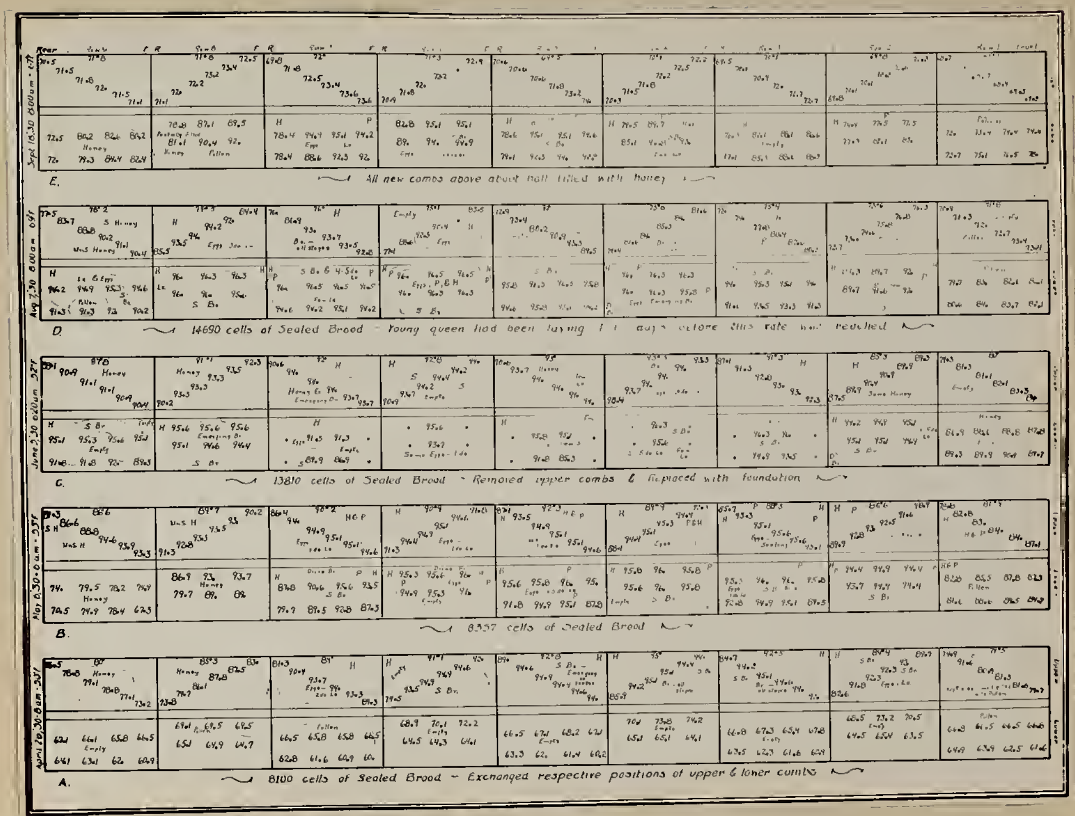

Plate 11

Brood temperature colony 59, single walled hive

Explanation of Plate 12

Method of Plotting:

See explanation of Plate 11.

Description of Periods:

Series A shows the entire brood nest located in the upper set of combs, numbers 2 to 6, inclusive (note also brood on March 22, Plate 13, Series C).

Series B shows the brood nest (April 26) expanded to include frame 7 which contained largely pollen on April 17.

Series C, D, E give the temperatures for three consecutive days and show the constancy of temperature within established brood areas and a rise in temperatures in expanding areas. Note the tendency for lower temperatures on the outer surface of the outside brood combs.

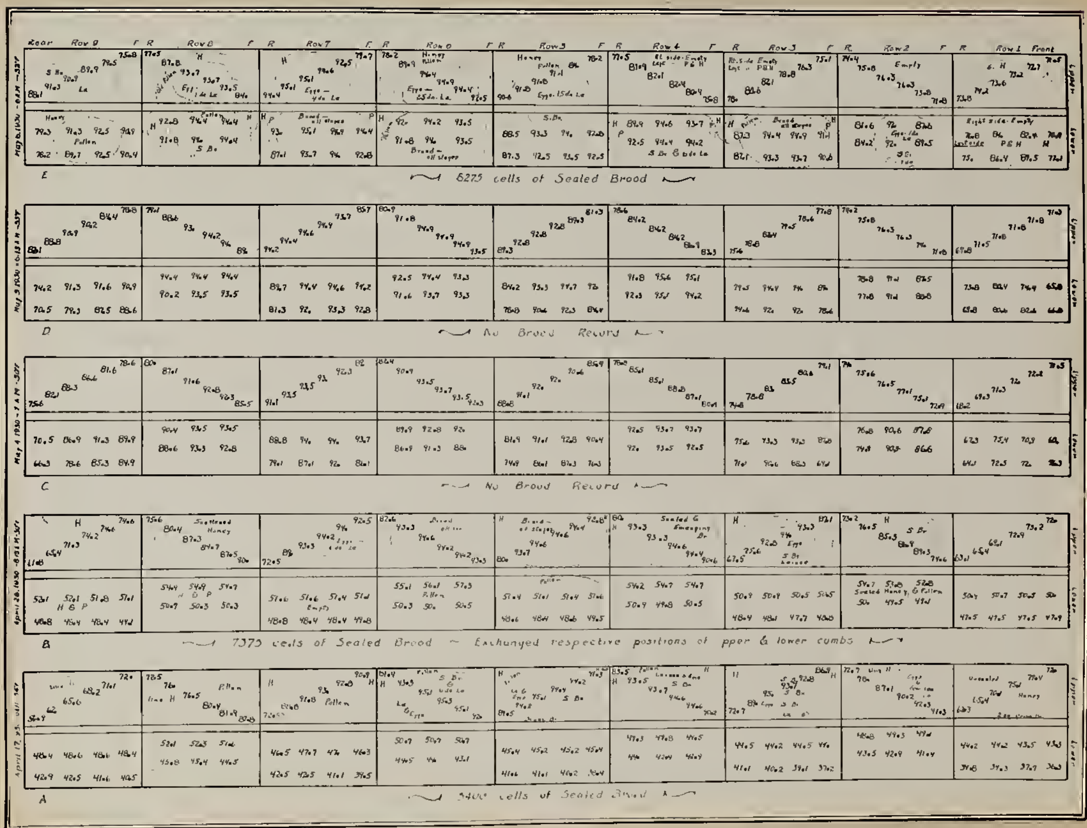

Plate 12

Brood temperatures Colony 60, double walled hive

Explanation of Plate 13

Method of Plotting:

See explanation of Plate 11. The clusters in Series A, B, C, and E were considered to have extended above the broken lines as diagrammed, based upon the temperatures recorded. Series D, the colony was opened after recording the temperatures and the approximate position of the cluster diagrammed. It is characteristic for the cluster to form in contact with the inner cover when located in the upper set of combs, as diagrammed in Series D.

Description of Periods:

Series A heavily insulated colony with an unusually large cluster. The extra insulation was applied Dec. 7; typical maximum and minimum hive temperatures in relation to those outside respectively were as follows: Dec. 8, 82-44-33; Dec. 11, 82-36-20; Dec. 12, 83-26-7; Dec. 20, 85-39-36; Jan. 4, 91-43-36, although temperatures were not taken between Dec. 21 and Jan. 4 (outside minimum 7.5°, Dec. 23; maximum, 0.48° Jan. 2). The maximum temperatures were above 90 after Jan. 4; brood from eggs to 3-day larvae were present on both sides of frame 4, Jan. 8, indicating that the queen began laying eggs about Jan. 2.

Series B, double walled hive, the upper and lower sets of combs were reversed Jan. 25 to determine whether the cluster could be induced to form below. A portion of the cluster maintained brood temperatures below but the main body of the cluster returned to the upper set of combs and within a short period reestablished the brood nest there.

Series C shows the cluster entirely established in the upper set of combs, rearing brood in three frames when the outside temperature fell to 16.5° F. on March 22.

Series D and E show the effects of 10° difference in the outside temperature on the size of the cluster and the temperatures maintained when not rearing brood.

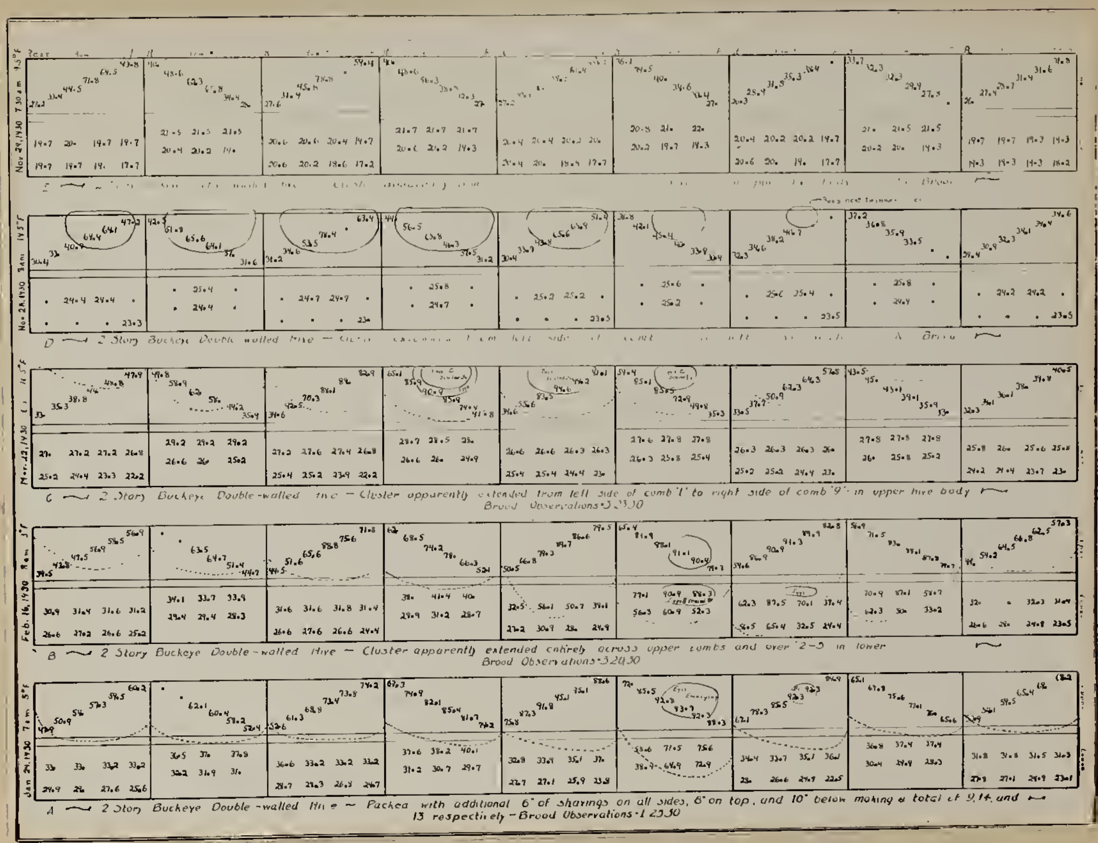

Plate 13

Winter temperatures Colony 60

Explanation of Plate 14

Method of Plotting:

See explanation of Plate 11.

A series of temperatures mapped in cross section through the center of the cluster for colony 60, 2-story double walled hive, from Nov. 3 to 26, showing the influence of changes in the outside temperature and of feeding sugar syrup on cluster temperatures and its activity. Where the outside temperature is sufficiently low, the estimated cluster area is enclosed by a broken line. Areas having temperatures favorable for brood-rearing are enclosed by a dotted line.

Brood-rearing temperatures are produced while the bees are taking syrup; eggs may be deposited, some of which may be allowed to develop; but the tendency to allow the cluster temperature to drop as soon as syrup is no longer available tends to lengthen the developmental period and is unfavorable for continued brood-rearing. Brood-rearing may be brought to a close as suddenly as initiated (compare temperatures following Nov. 20 including rows 7 and 8 Series D and E, Plate 13).

The six cells of recently sealed brood on the left side of frame 7, Nov. 18, must have resulted from the stimulation of high temperatures following the feeding on either Nov. 6 or 8. Similarly, eggs to 1-day larvae present Nov. 18 could have originated after Nov. 14, but the eggs were probably laid as early as Nov. 12 or 13, since the low cluster temperatures following Nov. 15 would have retarded their development.

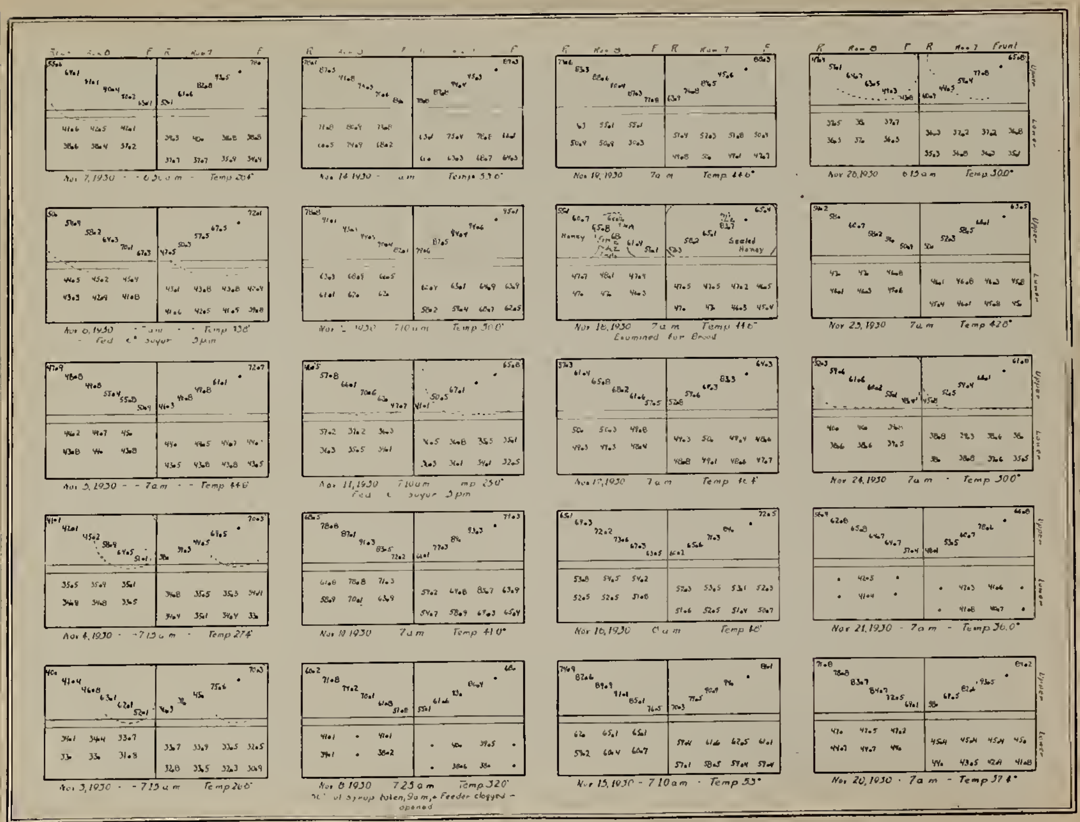

Plate 14

Winter Temperatures Colony 60, double walled hive

Explanation of Plate 15

Method of Plotting:

See explanation of Plate 11.

A series of temperatures mapped in cross section through the center of the cluster on either side of frame 5, colony 59 (single walled hive) and frame 7, colony 60 (double walled hive, further protected by an insulated case described under Plate 17) showing the effect on the cluster and hive temperature of a sudden drop in outside temperature. The areas enclosed by a broken line show the estimated position of the cluster.

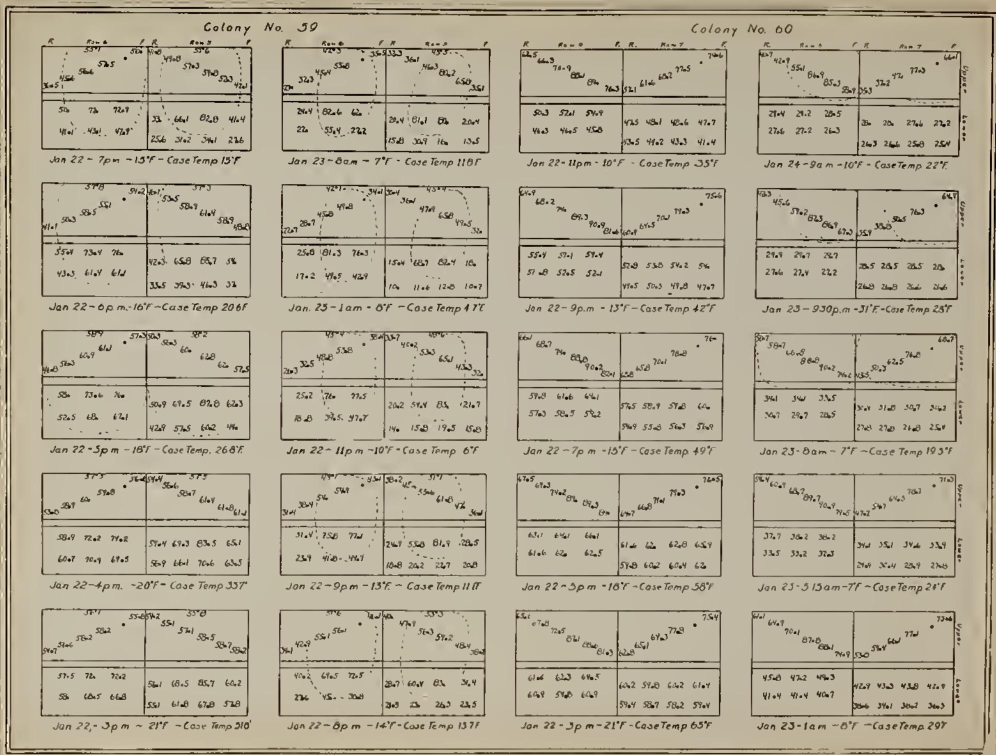

Plate 15

Winter temperatures, showing effect of a sudden drop in temperature on Colony 59, single walled hive; on Colony 60, well insulated hive

Explanation of Plate 16

Method of Plotting:

Graph showing the effects of a sudden drop in temperature on the cluster, housed in a 2-story single walled hive, with the entrance reduced to $\frac{3}{4}$". The location of the thermo-couples for which the temperatures are charted are shown in the lower left corner of the plate. The broken curves between 1 a.m. and 5:15 a.m. Jan. 23, serve only to emphasize the change in the time interval, where the change in temperature appears abrupt in the graph.

Description of the Periods:

The colony had been retained in a thermostatically controlled case during the previous three weeks under the conditions similar to those charted for Jan. 18 to 21. The top of the celotex lined case (one thickness of heavy felt roofing paper, 7/8" matched pine lumber and $\frac{1}{2}$" sheet of celotex) was removed and the heater shut off at 3:30 p.m., Jan. 22, and replaced at 1 a.m., Jan. 23. The outside temperature charted was approximately 3° higher than that in the immediate vicinity of the colonies under observation, due to the position of the thermometer which was on the opposite end of the building and at an elevation about fifteen feet higher. The upper set of combs were of new wax and had not been used for brood except for numbers 3, 4, and 5. The colony showed a noticeable aversion towards occupying these new combs which contained some honey but had plenty of open cells in which to cluster.

The first response to the sudden drop was a rise in temperature throughout the cluster, a condition which lasted about 90 minutes; this was followed by a very gradual decrease in the inner portion and a somewhat more rapid decrease towards the periphery, due to the contraction of the cluster; within $4\frac{1}{2}$ hours an upward shift of the cluster was apparent, and within 14 hours the center of heat was well established in the upper set of combs where it remained for 10 to 12 hours, before shifting back to the full set of dark combs below.

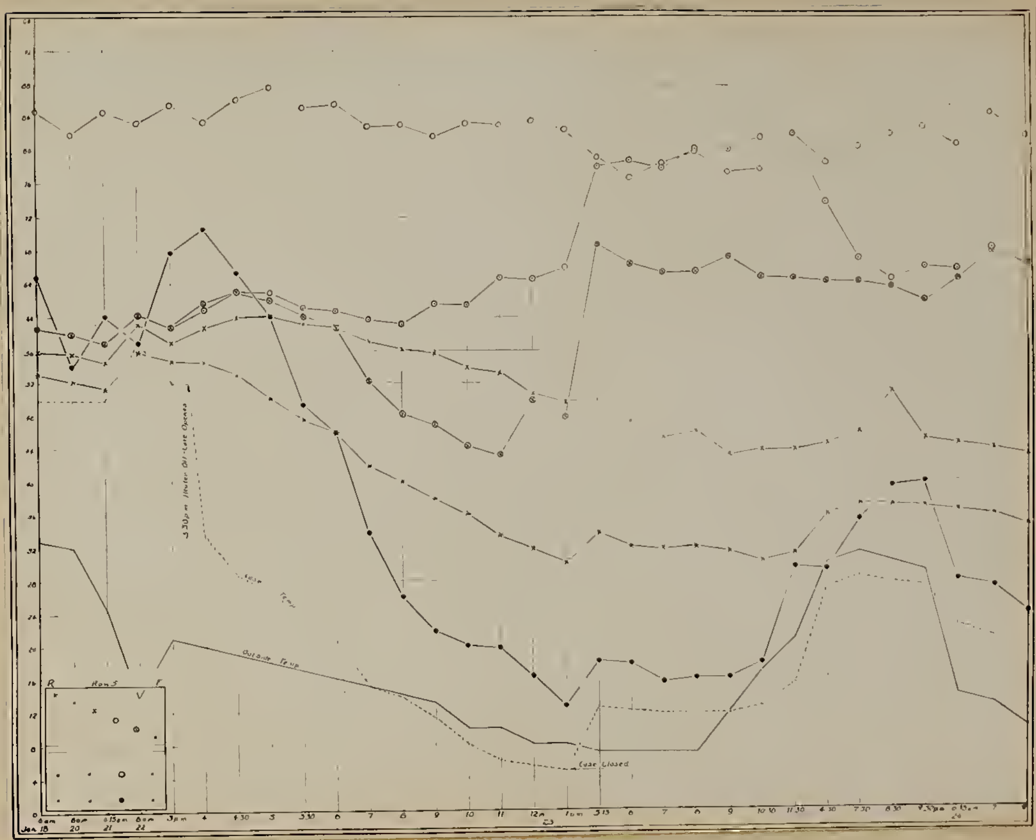

Plate 16

The effect of a sudden drop in outside temperature on the hive and cluster temperatures Colony 59, 2-story single walled hive

Explanation of Plate 17

Method of Plotting:

Graph showing in cross section the effects of a sudden drop in temperature on the cluster housed in a 2-story double walled hive, further protected by an insulated case in which each wall, including top and bottom, consisted of one thickness of heavy felt roofing paper, 7/8" matched pine siding, and two sheets of ½" celotex separated by a ½" sealed air space; an 8" air space was present between the inside of the case and the outside of the double walled hive; all joints interlocked; the entrance at the outer end of the tunnel was reduced to ¾".

Prior to Jan. 16 the colony had shown uniform temperature with the case held constant at 63° to 64°, except that when the outside temperature approached zero or below, the temperatures in the lower part of the hive were observed to range from 8° to 14° below that of the case. The heater was shut off 18 hours prior to the reading on Jan. 17. At that reading, the cluster was definitely located towards the front, in the upper hive body with a maximum temperature of 76°, a drop of 6° over that of the 15th. Brood-rearing temperatures were obtained within 36 hours after the heater was turned on.

The immediate response to a second drop at 3:30 p.m. Jan. 22 was a rise of 2° to 3° in the cluster; this was followed by a gradual decrease four to five hours later except in the regions where brood was evident. Those bees located on the lower set of combs before the heater was shut off again began to join those in the upper hive within 3 hours and had vacated the lower comb with 13 to 14 hours. Insulation while greatly reducing the rate of temperature decline, does not prevent freezing temperatures from penetrating the unoccupied spaces within the hive of a normal 2-story colony; it likewise tends to hold the low temperatures inside the hive for an extended period after the outside temperature shows a marked increase.

Plate 17

The effect of a sudden drop in the outside temperature on the hive and cluster temperatures Colony 60, well insulated hive

Plate 18

Plan of apiary as affecting the drifting problem; also showing wind protection; also photographs of packing methods.

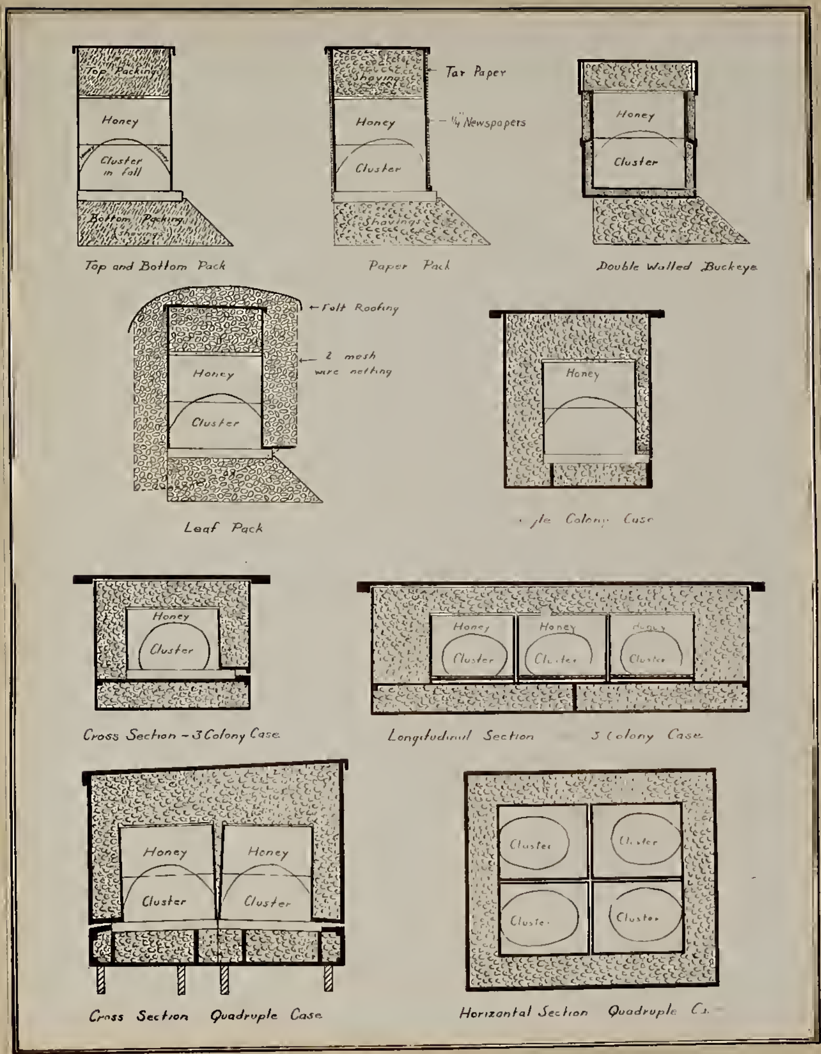

Plate 19

Diagrams of packing methods showing cluster location at the beginning of the winter period

Amherst, Mass., April 27, 1931.

The thesis submitted by Mr. Clayton L. Farrar in partial fulfillment of the requirements for the degree of Doctor of Philosophy has been approved by his Thesis Committee.

A. V. Osmun

C. P. Alexander

A. I. Bourne, Chairman